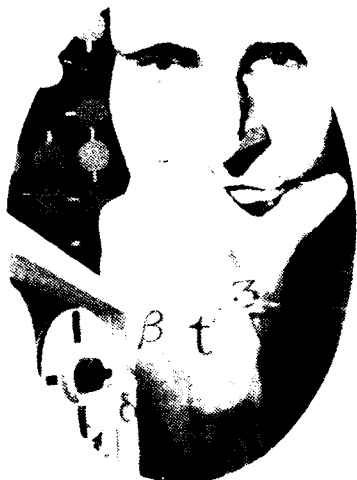


SEPTEMBER 1988

RESEARCH PROGRAM

AFCOSR-IR-89-0262

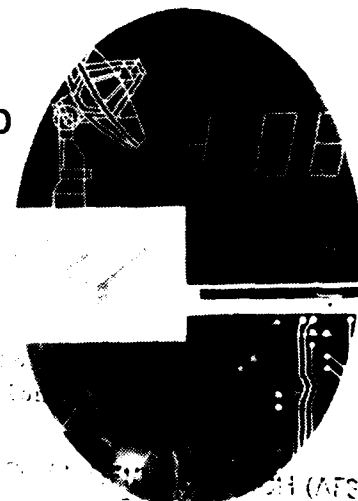
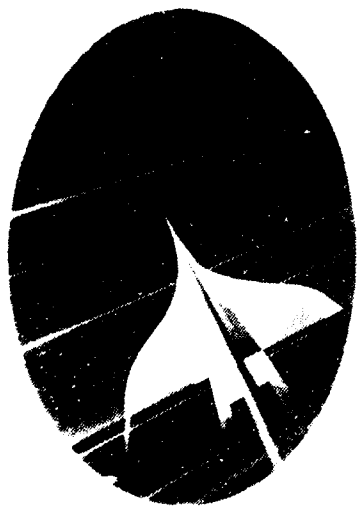


FY 1989
US AIR FORCE

RESEARCH TECHNOLOGY AREA PLAN



AIR FORCE SYSTEMS COMMAND
AIR FORCE OFFICE
OF
SCIENTIFIC RESEARCH
BOLLING AIR FORCE BASE D.C.



NOTICE

This Plan is given wide distribution within the U.S. Government and has been cleared for distribution outside the U.S. Government as an informational document to the research community. Technical descriptions and associated funding reflect FY 89 planning data at the time this Plan was prepared. However, budgetary changes and Air Force management decisions regarding research priorities may cause programmatic changes prior to program execution.

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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED			1b. RESTRICTIVE MARKINGS		
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release distribution is unlimited		
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE					
4. PERFORMING ORGANIZATION REPORT NUMBER(S)			5. MONITORING ORGANIZATION REPORT NUMBER(S) AFOSR-TR-89-0262		
6a. NAME OF PERFORMING ORGANIZATION AIR FORCE OFFICE OF SCIENTIFIC RESEARCH		6b. OFFICE SYMBOL (If applicable) AFOSR	7a. NAME OF MONITORING ORGANIZATION AFOSR		
6c. ADDRESS (City, State, and ZIP Code) BLDG. 410 BOLLING AFB, D.C. 20332			7b. ADDRESS (City, State, and ZIP Code) Bldg 410 BAFB DC 20332 6448		
8a. NAME OF FUNDING / SPONSORING ORGANIZATION AFOSR		8b. OFFICE SYMBOL (If applicable) XOP	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER In-house		
8c. ADDRESS (City, State, and ZIP Code) Bldg 410 BAFB DC 20332 6448			10. SOURCE OF FUNDING NUMBERS		
			PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.
					WORK UNIT ACCESSION NO.
11. TITLE (Include Security Classification) FY 1989 US AIR FORCE RESEARCH TECHNOLOGY AREA PLAN					
12. PERSONAL AUTHOR(S)					
13a. TYPE OF REPORT FINAL		13b. TIME COVERED FROM _____ TO _____		14. DATE OF REPORT (Year, Month, Day) SEPTEMBER 1988	
15. PAGE COUNT 101					
16. SUPPLEMENTARY NOTATION					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB-GROUP			
19. ABSTRACT (Continue on reverse if necessary and identify by block number) THE RESEARCH TECHNOLOGY AREA PLAN (TAP) DESCRIBES THE ACTIVITIES TO BE FUNDED UNDER DEFENSE RESEARCH SCIENCES (DRS), PROGRAM ELEMENT 0601102F.					
20. DISTRIBUTION / AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED		
22a. NAME OF RESPONSIBLE INDIVIDUAL ROBERT F. EDMUND, Lt Col, USAF			22b. TELEPHONE (Include Area Code) (202) 767-6010		22c. OFFICE SYMBOL AFOSR/XOP

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INTRODUCTION

The Research Technology Area Plan (TAP) describes the activities to be funded under Defense Research Sciences (DRS), Program Element 0601102F.

MISSION

The Air Force Office of Scientific Research (AFOSR) is the single manager of the Air Force Defense Research Sciences Program, which is funded by program element (PE) 0601102F. AFOSR is responsible for planning, managing, implementing, and controlling a high-quality basic research program. Specifically, AFOSR's goals are to maintain technological superiority in the scientific areas relevant to Air Force needs; to prevent technological surprise to our nation and create it for our adversaries; to maintain a strong research infrastructure composed of Air Force laboratories, industry, and universities; and to complement the national research effort.

AFSC Regulation 23-15
Organization and Mission--
Field, Air Force Office of
Scientific Research
17 May 1984



A-1

In executing the DRS program, AFOSR and its researchers strive to fill the Air Force research requirements for the future and meet the challenge established by General Bernard P. Randolph, Commander, Air Force Systems Command.

★ ★ ★ ★

COMMANDER'S POLICIES

"It is the mission of this command to develop, acquire, and deliver the weapons that will allow our world-wide forces to deter war or, if necessary, to allow them to fight and win. ...I have selected three goals to focus our attention on our mission."

MEET OUR USERS' NEEDS

MAINTAIN ACQUISITION EXCELLENCE

ENHANCE OUR TECHNOLOGICAL SUPERIORITY

General Bernard P. Randolph
Commander

ORGANIZATION

Research is one of 13 technology areas within Air Force Systems Command managed by the Deputy Chief of Staff for Technology and Requirements Planning (HQ AFSC/XT) who is the Science and Technology Program Executive Officer (S&T PEO). The Program Manager for Research is the Air Force Office of Scientific Research Commander (AFOSR/CC).

AFOSR is directly subordinate to HQ AFSC and includes Detachment 1, AFOSR, European Office of Aerospace Research and Development (EOARD); Detachment 2, AFOSR, Frank J. Seiler Research Laboratory (FJSRL); and the Far East Operating Location (AFOSR/FE).

The Air Force Office of Scientific Research is the single manager of the Defense Research Sciences Program. The DRS program is divided into 13 scientific projects and managed by six scientific directorates. The AFOSR organizational structure is presented in Figure 1.

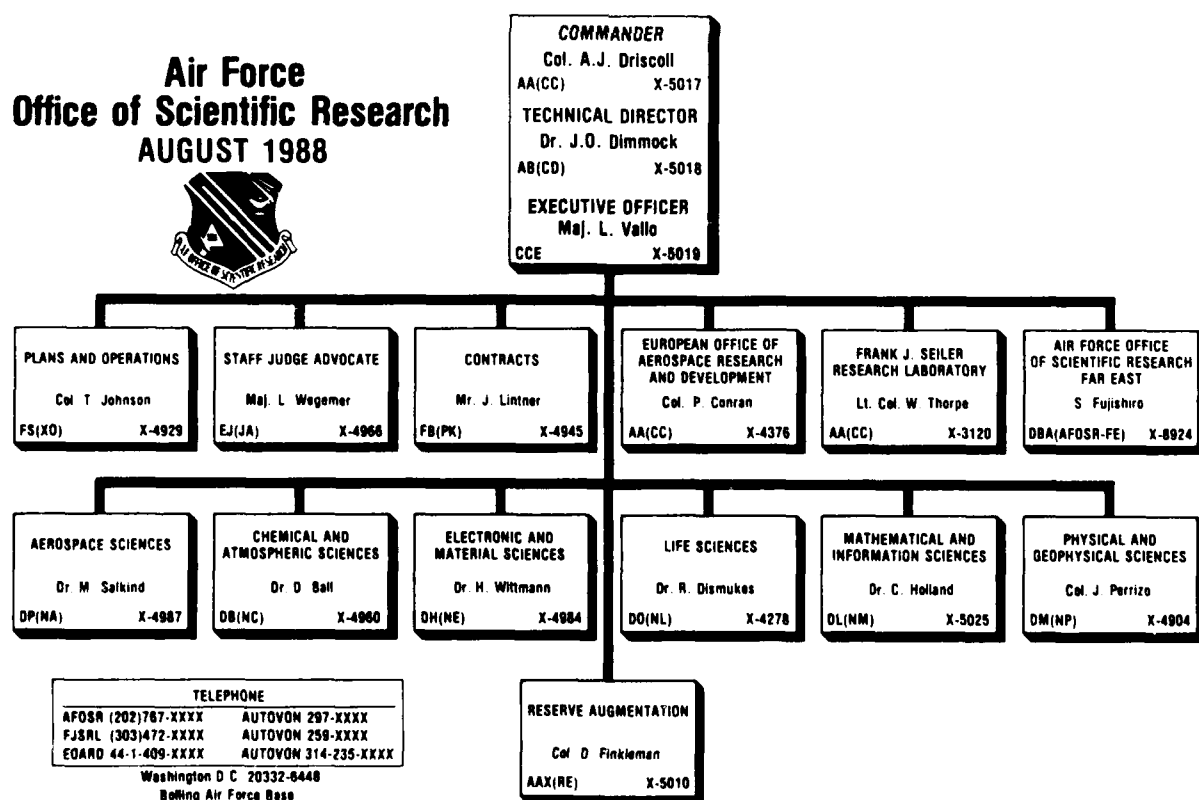


Figure 1. The Air Force Office of Scientific Research

The Directorate Project assignments are as follows:

<u>DIRECTORATE</u>	<u>PROJECT</u>
Aerospace Sciences	2302, Structures 2307, Fluid Mechanics 2308, Energy Conversion
Chemical and Atmospheric Sciences	2303, Chemistry 2310, Atmospheric Sciences
Electronic and Material Sciences	2305, Electronics 2306, Materials
Life Sciences	2312, Biological and Medical Sciences 2313, Human Resources
Mathematical and Informational Sciences	2304, Mathematics
Physical and Geophysical Sciences	2301, Physics 2309, Terrestrial Sciences 2311, Astronomy and Astrophysics

In executing the DRS program, AFOSR:

- Manages an extramural research program involving universities, non-profit organizations and industrial research organizations.
- Provides overall management for research conducted on-site and under contract at the following Air Force organizations:

- Air Force Armament Laboratory (AFATL)
- Air Force Engineering Services Laboratory (AFESL)
- Air Force Space Technology Center (AFSTC)
 - Air Force Astronautics Laboratory (AFAL)
 - Air Force Geophysics Laboratory (AFGL)
 - Air Force Weapons Laboratory (AFWL)
- Air Force Wright Aeronautical Laboratories (AFWAL)
 - Aero Propulsion Laboratory (AFWAL/PO)
 - Avionics Laboratory (AFWAL/AA)
 - Flight Dynamics Laboratory (AFWAL/FI)
 - Materials Laboratory (AFWAL/ML)
- Human Systems Division (HSD)
 - Air Force Human Resources Laboratory (AFHRL)
 - Armstrong Aerospace Medical Research Laboratory (AAMRL)
 - USAF School of Aerospace Medical Research Laboratory (USAFSAM)
- Rome Air Development Center (RADC)

- Operates and administers three subordinate units: EOARD, FJSRL and AFOSR/FE. EOARD monitors European and Middle Eastern research and development, AFOSR/FE monitors research in the Far East, and FJSRL performs research in aerospace mechanics, chemical sciences, and physics. FJSRL also provides research opportunities for the USAF Academy faculty and cadets.
- Conducts several special programs that sponsor Air Force and university researchers working on problems of interest to the Air Force.
- Maintains an Air Force Reserve group that, in addition to its peacetime duties, is capable of providing research support to solve Air Force problems during a national emergency.
- Provides the Air Force focal point for the Strategic Defense Initiative program in Innovative Science and Technology.

I. GUIDANCE

The research efforts in this Technology Area Plan (TAP) are based upon the guidance in Air Force System Command's Air Force Science and Technology and Development Planning Program for 1988.

In the 1988 AF S&T Program Pamphlet, AFSC identified the following areas for increased emphasis:

- Materials
- Electronics
- Photonics
- Superconductivity
- Computational Sciences
- Expert Systems
- Sensor fusion to advance capabilities in wide area surveillance, tactical reconnaissance, cockpit situational awareness (supercockpit), and autonomous guided armaments--particularly multi-mode/multi-spectral sensors, multi-static receivers and expert system-aided decision making
- Directed energy technologies
- Military spacecraft technologies/integration to achieve survivability, increase life, and provide for multi-mission/adaptive capabilities.
- Reliability, maintainability, and producibility considerations for advanced technology developments to increase sortie generation and reduce operating costs
- Smart built-in-test (SMART BIT)
- Unified Life Cycle Engineering

In the FY 88 guidance the following areas were identified for continued emphasis:

- High Performance Turbine Engine (HPTE)
- Hypersonic technology investments in basic research and exploratory development
- High Energy Density Propellants and other advanced propulsion concepts
- Civil and environmental engineering to enhance air base operations
- Vertical Short TakeOff and Landing (VSTOL) technologies

In addition to the guidance contained in the S&T Pamphlet, the Department of Defense, Air Staff, and Air Force Systems Command provide guidance to AFOSR and the Air Force laboratories throughout the DRS planning cycle.

The Air Force research planning and review process is the formal mechanism by which the investment strategy is translated into a research program. The planning process is formalized by documentation and a series of reviews that are scheduled throughout the fiscal year. The entire process, from initial guidance to final review of the research results, spans three years. A typical cycle is shown in Figure 2.

The planning process begins in September, 25 months before the start of the fiscal year when the Scientific Directors provide the Commander with project recommendations. AFSC/XI and Air Staff RDT&E (J-Panel) review these recommendations. In January, 21 months before the fiscal year starts, the Commander and Technical Director provide the Scientific Directors with guidance for the Core Program and Initiatives. A complete review of the proposed program, including both Core and Initiatives, is held with HQ AFSC/XI, Air Staff, and Laboratory participation in March. Resultant budget guidance is provided to the Scientific Directors in March, which also provides input to AFSC for the POM 18 months before the start of the fiscal year. Directorate task allotments are approved by the Commander and Technical Director in April.

The Scientific Directors distribute the project funds to the tasks. On the basis of the funding guidance, task Plans are developed and submitted to the Scientific Directors for review and approval. The Research Technology Area Plan is published outlining the coming fiscal year's program.

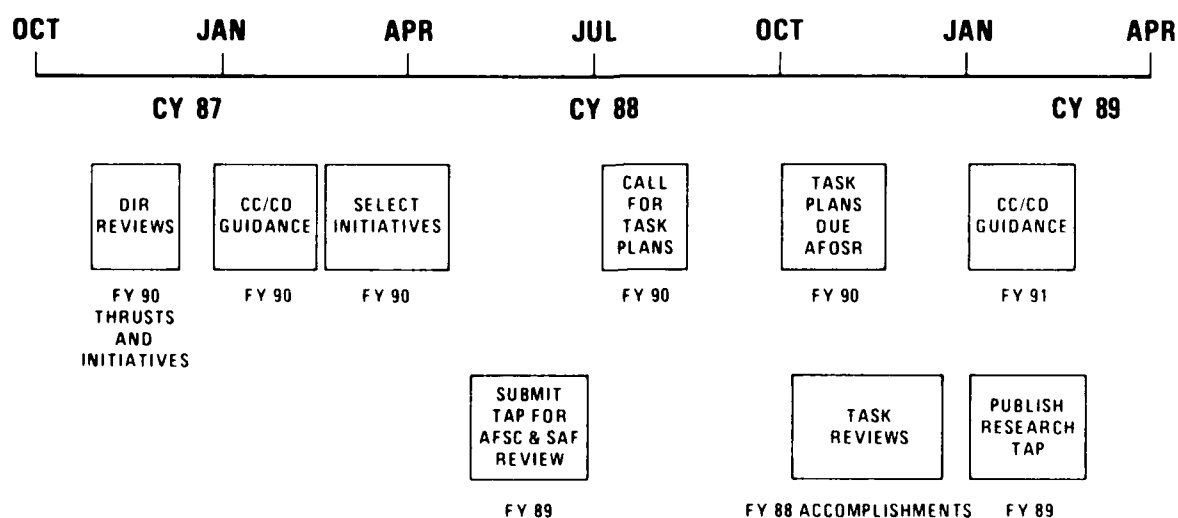


Figure 2. AFOSR Planning Process

Finally, in October and November following completion of the fiscal year, each Task Manager briefs the Commander and the Scientific Directors on task accomplishments, the research program to be attempted during the following year, and the fiscal status of the task. These reviews are frequently held at the Air Force Laboratories most actively involved in the program. The AFSC staff, the chief scientists of the Laboratories, and DOD personnel also attend these briefings. Program adjustments are made on a continuing basis to reflect the most current funding picture.

Throughout the process, approved plan alterations and funding changes are included in the "living" plan, which is maintained at AFOSR.

Coordination

AFOSR coordinates its diversified, broad-based research program with Air Force Laboratories, Product Divisions and Centers, other Services, and various Federal agencies. Much of the basic research program feeds directly or indirectly into existing Laboratory Exploratory Development (6.2) programs. Other research efforts result in revolutionary breakthroughs which initiate new 6.2 programs. AFOSR personnel brief the various Product Divisions and Centers on selected scientific achievements and ongoing research that applies to their needs. AFOSR also publishes a Recent Research Accomplishments brochure describing scientific achievements sponsored under the Air Force DRS program. The research program is the subject of an annual Investment Strategy Review presented to the Office of Secretary of Defense (OSD) and HQ AFSC.

AFOSR coordinates its research program with the other Services through scientific meetings, workshops, and exchange of proposal lists and funding actions.

In addition, AFOSR coordinates research efforts with various other Federal agencies, including the National Aeronautics and Space Administration, Federal Aviation Administration, National Science Foundation, Department of Energy, National Institutes of Health, US Geological Survey, National Security Agency, Defense Nuclear Agency, Defense Advanced Research Projects Agency, Environmental Protection Agency, National Oceanic and Atmospheric Agency, and National Bureau of Standards.

Industry conducts Independent Research and Development (IR&D) programs which are evaluated by an assigned DOD agency. AFOSR has oversight responsibility for IR&D at seven industrial laboratories that specialize in basic and applied research: GE/Corporate R & D (Schenectady, NY), Honeywell/Corporate Tech Center (Bloomington, MN), Honeywell/Systems & Research Center (Minn, MN), IBM/Research Division (Yorktown Hts, NY), Martin Marietta/Laboratories (Baltimore, MD), McDonnell Douglas/Research Labs (St. Louis, MO), and Rockwell/Science Center (Thousand Oaks, CA). This oversight responsibility involves technical plan evaluations and on-site visits that give Air Force scientists an opportunity to assess industrial programs and to encourage industrial researchers to include research of interest to the Air Force.

II. FY 89 DEFENSE RESEARCH SCIENCES INVESTMENT PLAN

Research is the Air Force's investment in the future. It is an investment in the technologies and weapons systems the Air Force must have to meet the challenges of the twenty-first century.

As manager of the Air Force Defense Sciences Research (DRS) program, the Air Force Office of Scientific Research (AFOSR) supports research in all scientific disciplines contributing to the Air Force mission. Philosophically, the program is structured to increase scientific and engineering knowledge related to long-term national security needs. The research program ensures that personnel with the technical expertise to support the Air Force research requirements are available at Air Force laboratories, at universities, and in industry.

The DRS program is managed by six scientific directorates and broken into 13 scientific projects. The funding levels for the directorates and for the projects are shown in Figures 3 and 4, respectively.

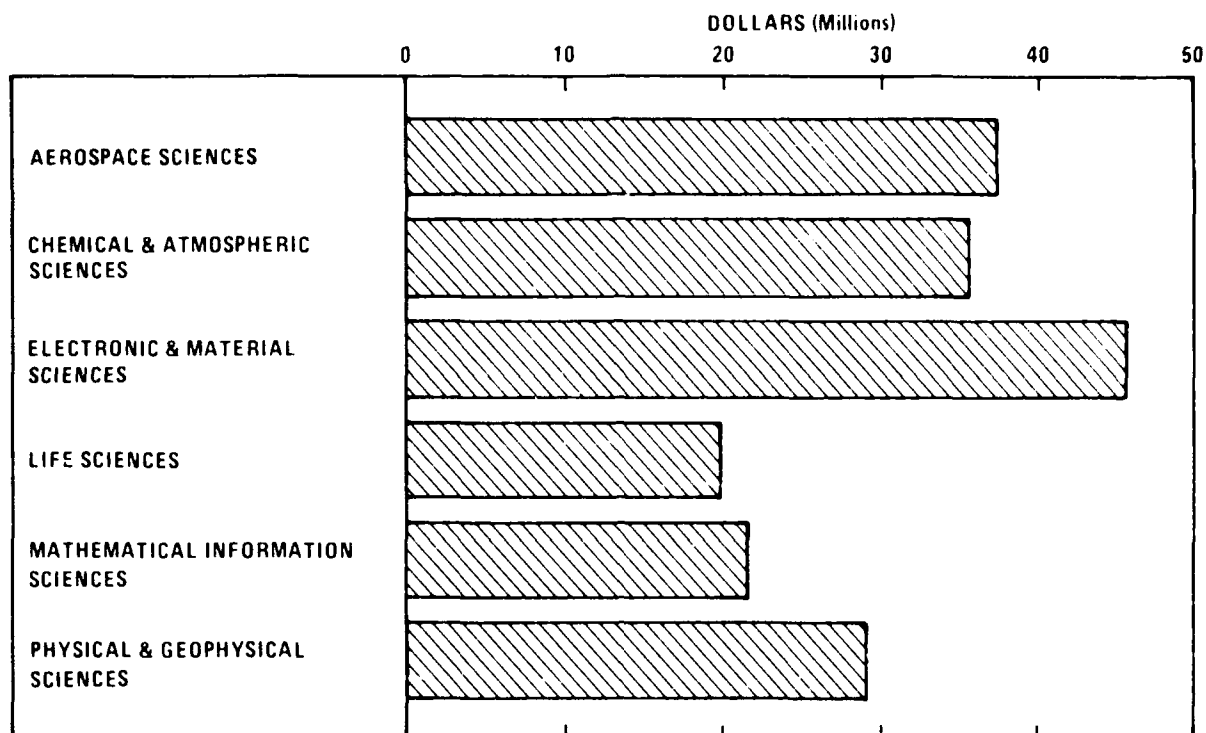


Figure 3. FY 1989 Air Force Research Funding by Directorate

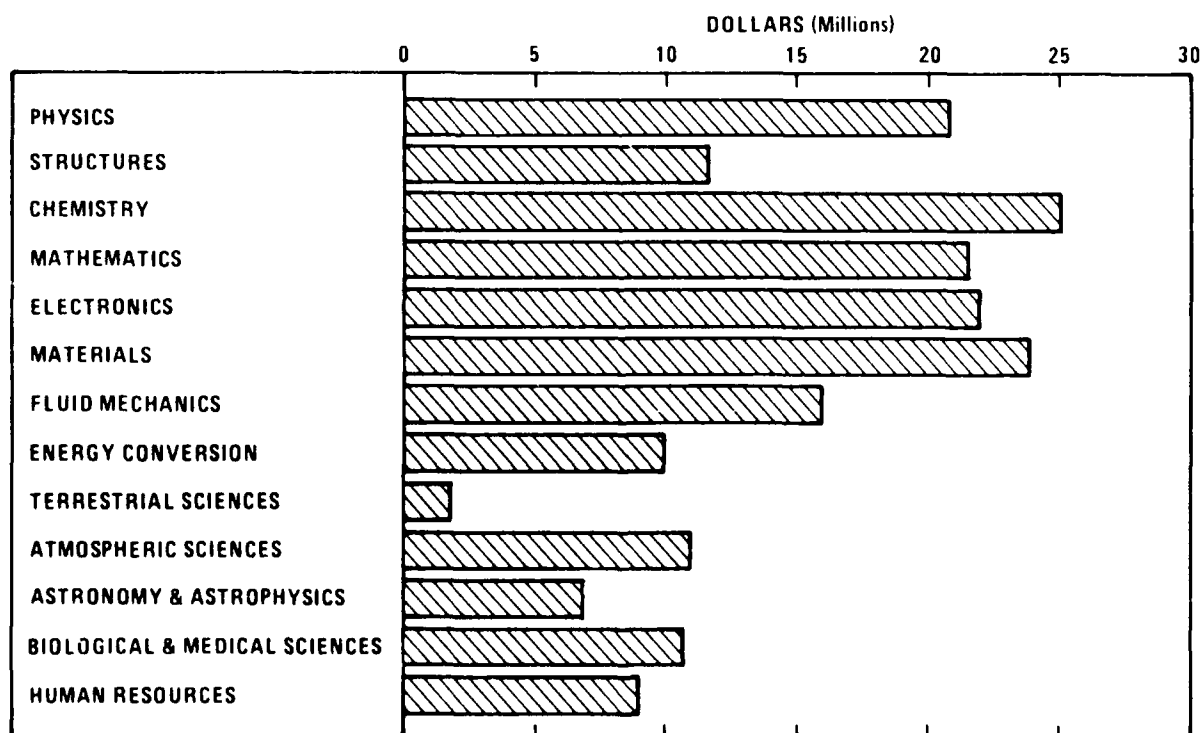


Figure 4. FY 1989 Air Force Research Funding by Project

III. RESEARCH SCIENCE PROJECTS

The Defense Research Sciences Program is managed under 13 scientific projects. Descriptions of these 13 scientific projects, are presented in this section.

For each project a description of the project and its general objectives are presented. This is followed by a more detailed description of the research efforts for each project, the objectives and applications of the effort and how these research efforts relate to other efforts within the Air Force, the other services, the Department of Defense and other government agencies. Finally under Initiatives, a brief summary of new activities planned for FY 89 are presented for each research effort. A more complete description of the FY 89 Initiatives is contained in Section IV.

AFOSR Focal Point: Col Jerry J. Perrizo
Telephone: (202) 767-4904

A. PROJECT 2301, PHYSICS

1. PROJECT DESCRIPTION: This project provides scientific information and knowledge which will pave the road for the development of advanced weapon concepts and advance the state of the art in systems development, electromagnetic countermeasures, nuclear weapons effects, communications and radar, nondestructive and nonintrusive testing and analysis, and new materials development. To provide the necessary scientific knowledge, work is supported in optical physics, plasma physics, atomic and molecular physics, particle beam physics, pulsed and prime power generation, and advanced energy concepts.
2. GENERAL OBJECTIVE: This project supports physics research that is expected to open up a vast array of opportunities for defensive aerospace weapon concepts and systems.
3. RESEARCH EFFORTS:

PHYSICS

Research will concentrate on the following physics specialties: optical physics (short wavelength lasers, integrated optical/ electronic devices, nonlinear optics, x-ray optics); plasma physics (artificial atmospheric plasmas, accelerators, and millimeter-wave plasma sources); atomic and molecular physics (atomic excitation and quenching processes, structure and dynamics of excited atoms, laser-matter interactions); particle beam technology (ion sources, neutralizers beam propagation and interaction); multimegawatt space prime power generation (storage, conversion of thermal energy to electricity, thermal management of waste heat, new electric power concepts for space).

A new initiative in nonlinear optics will emphasize nonlinear optical materials; techniques for coupling, phasing and tuning laser arrays; and means of optical frequency conversion to achieve efficient, compact devices at any desirable wavelength. In the field of plasma physics, a fundamental understanding will be sought for plasma turbulence that blocks effective use of plasmas for reliable sources of coherent millimeter-wave radiation. Work will begin on a plasma physics expert system which will employ a user-friendly, microcomputer-based, graphical interactive front end to interface plasma physicists with sophisticated, multidimensional simulation codes run on new classes of supercomputers. The result will be a computational hardware/software "user facility" of world-class stature which can be supplied to DOD researchers, at virtually no cost, for studying an almost limitless variety of basic and applied plasma physics questions. In anticipation of an FY 89 Initiative, research is being funded in the area of channeling radiation as a possible future source of coherent gamma rays.

Research will be conducted on the use of ultrashort laser pulses to probe collisional interactions of atomic and molecular species and their interactions with surfaces. Research will also be supported in the low energy physics of antimatter. This research is expected to eventually result in new forms of high energy density propellants and explosives. Project 2301 supports Forecast II initiatives in Space Power, Photonics, Cooling of Hot Structures, Directed Energy Technology, Antiproton Technology, Nonlinear Optics, and Plasma Defense Technology.

Objectives and Applications: Physics research focuses on the properties and behavior of matter at the most fundamental level. Major discoveries in physics are likely to lead to significant advances in military technology and tactics. Maxwell's electromagnetic theory, for example, forms the basis for understanding electromagnetic phenomena from waves to plasmas and spawned the radio, television, radar, and modern communication systems. Quantum mechanics made possible the invention of the transistor, solid state electronics, and the laser. The demonstration of the maser in 1953 and the laser in 1960 revolutionized military tactics for weapon delivery rivaling the impact of the radar in World War II. Other outstanding examples are nuclear fission and fusion, photoemission (for night vision), and x-rays. Progress in physics over the last decade has been remarkable.

The following are specific applications of this research to Air Force technology programs:

- a. Study the generation and dissipation of atmospheric plasmas.
- b. Provide a data base for chemical agent remote detection.
- c. Increase the efficiency and performance of existing laser systems.
- d. Evaluate the potential of new high power laser concepts.
- e. Develop new, efficient high power lasers operating at shorter wavelengths.
- f. Provide improved laser gyro operation by improving mirror quality.
- g. Develop new laser resonator devices which can correct for medium inhomogeneities and mirror distortions.
- h. Develop new laser mirrors and window materials by depositing selected well-controlled coatings on the support material.
- i. Improve propagation capabilities to deposit radiative energy on target.
- j. Predict results of intense laser interactions with materials.
- k. Demonstrate the feasibility of particle beam generation and propagation.
- l. Develop new energy storage and switching devices for pulsed power

application.

m. Evaluate the potential of new microwave and millimeter wave source concepts for use in communications, electronic counter measures (ECM), radars, and weapon concepts.

n. Develop a knowledge base that permits the production, storage and controlled use of antimatter as a future source of energy.

o. Provide advanced propulsion concepts.

p. Develop neutral particle beam technology.

q. Develop diagnostic techniques for the study of hostile environments such as aircraft turbine engines.

r. Develop multimegawatt prime electrical power systems for future space-based directed energy weapons and surveillance systems.

s. Develop more accurate time standards for navigation and communication purposes.

Relationship To Other Programs: The Army, Navy, Defense Advanced Research Project Agency, Strategic Defense Initiative Organization and National Science Foundation sponsor and participate in research that is complimentary to ours. And we participate in each other's reviews. The AFOSR Program Manager for SDI research sponsors complementary AF physics research and coordinates the non-physics SDI research efforts with the other AFOSR Program Managers.

Initiatives: In the Wafer Scale Union initiative, materials, techniques (particularly optical techniques), device concepts, and integration schemes will be studied to advance the state-of-the-art of integrating microwave, optical, electronic, mechanical, and sensor elements on single wafers to perform complex system functions compactly and inexpensively.

In the Half-Collisions initiative laser excitation will be used to put molecules into well defined states which in a "full-collision" process would correspond to one of many intermediate or transition states. The molecules will then dissociate into fragments which will follow trajectories similar to those of the second half of a collision between the fragments. Thus the analysis of the second half of the "collision" is more tractable than in the corresponding "full collision" where the initial states of the colliding particles may be well defined, but the many possible intermediate and final states make the analysis of the results more difficult. Experimental and theoretical studies of these "half collisions" will be conducted.

AFOSR Focal Point: Lt Col George Haritos
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B. PROJECT 2302, STRUCTURES

1. PROJECT DESCRIPTION: Interdisciplinary research is pursued in aerospace structures-related topics, including dynamics and stability, damage processes and mechanisms, and response of structures and materials. This work provides the basic understanding and methodology necessary for cost-effective design and safe operation of superior aerospace weapon systems and installations. This research directly supports the development of several aerospace systems, including the National Aerospace Plane (NASP), the Advanced Tactical Fighter (ATF), and the Integrated High Performance Turbine Engine Technology (IHPTET) program.

2. GENERAL OBJECTIVE: The rapidly approaching era of hypersonic flight, space-based operations, actively controlled/precisely-aimed space systems, and impact-resistant aerospace vehicles and survivable installations will place extraordinary performance and reliability demands on structural materials and systems. Research in this project seeks a fundamental understanding of advanced structural materials for evolving aerospace systems and installations. A look to the future reveals more flexible, highly maneuverable, actively-controlled aircraft which are fuel efficient, reliable, and easy to maintain; also, larger and more flexible space structures that can be accurately pointed through active control. Increased emphasis in conventional warfare will require alternate launching and recovery surfaces, runways which can be rapidly repaired, and highly survivable easily-dispersed tactical structures. Such future needs focus attention on the shortcomings of our current understanding and help to define future research needs.

3. RESEARCH EFFORTS:

DYNAMICS AND STABILITY

Aircraft, spacecraft and missile structural system operational environments demand that their design, qualification, and operation be based on dynamic response considerations, including loading, stability, and durability. Our research seeks to meet this demand by developing analytical and experimental methods of characterization and response prediction, investigating the stability and durability implications of dynamic response, and techniques for controlling all aspects of the response.

For the characterization of dynamic response in highly flexible structures undergoing high rate maneuvers or high frequency excitation, we are pursuing a modeling concept based on nonlinear elasticity. We are developing modern stochastic techniques to identify and quantify the effects of excitation noise and of random variations in the structural characteristics of the

dynamic response.

Objectives and Applications: Nonlinearities effects on dynamic response are being identified and classified in terms of frequency-spectra, phase-plane attractors, and Poincare' maps. Criteria, in terms of the physical parameters and sensitivity of governing equations, are being established to define conditions under which a physical system transitions from periodic to chaotic behavior. We are seeking to identify more precisely the mechanisms of friction and to model them realistically in structural dynamic response equations.

We are promoting development of active and passive schemes for the control of dynamic response. Passive concepts under investigation range from tailoring material properties for damping enhancement to the inclusion of energy dissipation devices in system design. Active feedback control technology is being extended in many directions to permit application to highly flexible and distributed structures. For aircraft systems, the interactions among structural dynamics, aerodynamics and controls are being investigated in an integrated aeroservoelastic research. We are seeking to exploit new developments in the physical and mathematical sciences, such as piezoelectric polymers and ceramics, and parallel computing for dynamic analysis control. Specific applications are:

a. Prediction of structural response to system operational environments and their consequences in terms of strength, stability and durability.

b. Active control and aeroelastic tailoring concepts for stability augmentation and load alleviation in aeronautical systems, and for shape control and rapid decay of vibrational disturbances in precision space structures.

Relationship to Other Programs: The dynamics and control of Large Space Structures (LSS) is of paramount concern to the SDI program. A University Research Initiative (URI) center at Cornell is engaged in work on dynamics and control of LSS.

Initiatives: The incorporation of mesomechanical characterizations of structures will have a fundamental impact on our ability to create accurate dynamic models and in turn, to control system responses. The results are eagerly awaited since standard engineering linear dynamics and control laws are clearly inadequate.

DAMAGE PROCESSES AND MECHANISMS

When structural materials are placed into service, they develop flaws that interact and grow resulting in failures. Structural durability is governed by the characteristics of these flaws and their influence on the overall mechanical behavior and service life of the component. Influencing the durability of structural systems requires identification of the origins and growth characteristics of such flaws under service conditions, such as mechanical and thermal loading and environment, and mathematical modeling of the damage process.

Objectives and Applications: This research effort aims to identify the physical mechanisms under which microflaws in materials grow and interact with each other; using nonlinear fracture mechanics principles and high resolution experimental techniques, examine damage zone strain fields to develop general damage growth laws and prediction methods, accounting for the probabilistic manifestations of microstructural effects; identify damage states in composites and develop applicable damage metrics -- of particular interest is the initiation and growth of damage under mixed-mode loading conditions as influenced by constituent material properties and interface characteristics; and for geological materials, develop quantitative theories linking microscopic and macroscopic fractures based on reliable measurements, e.g., in-situ testing.

This work directly supports several future aerospace systems, including NASP, ATF, and IHPTET, by establishing methodologies for dealing with many critical issues. The following is a partial list of scientific/engineering issues directly addressed by this research effort.

a. Use stress-intensity based fracture mechanics methods to establish the degradation of mechanical properties and remaining service life (residual strength, life) in aerospace structural materials containing flaws which propagate under service conditions. Materials of interest include metallic alloys and superalloys suitable for airframe and engine applications, advanced composite systems, including polymeric resins, ceramics, metal-matrix, and carbon-carbon, and solid rocket propellants and liners. Gradually shift emphasis toward evolving nonlinear fracture mechanics treatments. This work directly supports the Air Force Aircraft Structural Integrity Program (ASIP).

b. Develop mechanics appropriate for multiphase materials. Identify and describe mathematically the damage mechanisms responsible for material degradation. Describe the deformation response to a broad range of excitations, including mechanical, thermal, chemical, and electromagnetic pulses. Characterize the micromechanical interactions between individual particles and proper constitutive modeling of geologic materials. Once the fundamental principles, descriptions, and methodologies have been established, apply this information to improve damage evolution predictions, residual strength, and safe service life. Serves a number of evolving aerospace programs, including ATF, NASP, and IHPTET.

c. Establish the technology base necessary to develop innovative methods for observing the response of structural materials to service-related loads in real time, remotely, and at high temperatures. Use these basic tools for the transition to direct measurements of individual constituents' properties in-situ, and under very high strain conditions. Develop rational testing methods for rapid evaluation of geologic materials to allow siting of tactical and strategic structures. Supports development of NDT&E procedures for advanced structural materials.

d. Formulate a thermo-inelasticity theory that can be used for both hot aerospace structures and high-energy weapons programs. This will require resolution of such basic issues such as (1) selecting appropriate thermodynamics theory (reversible, irreversible, equilibrium, etc.) for

deriving the field equations, (2) choosing an appropriate reference system (Lagrangian vs. Eulerian description), (3) generalizing Fourier's Law to include thermal relaxation, and (4) investigating the existence of variational principles appropriate for the thermo-inelasticity theory. Once these fundamental issues are resolved, this work will pursue aeroelasticity-related issues including active control and aeroelastic tailoring for stability augmentation, load alleviation, shape control, and rapid decay of vibrational disturbances. This work supports evolving aerospace systems which will operate under extreme temperature-gradient conditions, such as the NASP and IHPTET programs.

Relationship to Other Programs: The objectives of the mesomechanics research thrust were established after close coordination and cooperation with the Army Research Office, NASA, the National Science Foundation, and the Office of Naval Research. Strong ties have also been established with several industry IR&D programs, such as those at General Electric (OH), Pratt and Whitney (FL), United Technologies Research Center (CT), and Rockwell International Science Center (CA).

Initiatives: The FY 1989 Mesomechanics Initiative seeks to establish the correspondence between microstructural features and mechanical behavior so that the microstructure of structural materials can be designed for optimum performance.

RESPONSE OF STRUCTURES AND MATERIALS

The accurate prediction of weaponry effects on structural systems requires advances in modeling techniques for multi-phase materials and composite structures. To achieve this, it is necessary to improve the fundamental understanding of the inelastic dynamic behavior of materials, the characteristics of structural systems under impactive and shock loads, and interface phenomena including intergranular friction and chemical phase transformations in the material systems.

Objectives and Applications: This research effort will focus on the development of a sound theoretical basis for the modeling of impactive resistance of structures and materials under rapid loadings. The effort also aims to characterize the deformation and failure behavior of inelastic solids and concrete. Rational structural synthesis approaches will be developed based on a better understanding of the dynamic response of complex systems. Bond and interfacial effects and the energy dissipation mechanisms for complex and new material systems will be thoroughly investigated.

The technology applications are:

- a. Accurate prediction of impactive resistance and penetration of material and structural and mechanical systems.
- b. Damage tolerant design concepts for ensuring integrity and durability of structural subsystems.
- c. Accelerated nondestructive methods for evaluating advanced construction materials.

d. Improved site selection and soils evaluation techniques for construction of major Air Force systems.

e. Enhanced survivability of Air Force systems to ground motions resulting from blast loading.

f. Improved materials and design criteria for unsurfaced or minimally surfaced runways.

g. Development of better materials for rapid runway repair.

h. Development of alternate launch/recovery surfaces for immediate aircraft operations after attack by nonlinear weapons.

i. Development of better construction material system to withstand multiple nearby nuclear and non-nuclear detonations.

j. Improved design of protective structures through development of rational mathematical models for analyzing hardened structural systems.

Relationship to Other Programs: This work directly supports the engineering and services programs for the development of improved and more durable pavements for air field runways, including Rapid Runway Repair and Alternate Launch and Recovery Surfaces. It also supports the development of improved tactical and strategic protective structures, and new weapons. Therefore programs such as Advanced Silo Hardening, Silo Technology Program and Sensored Fused Weapons will benefit from the results of these research efforts.

Initiatives: Mesomechanics contributes to the research of penetration mechanics, interface phenomena, and inelasticity. The improved constitutive modeling from mesomechanics can contribute to all areas of structures and materials.

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C. PROJECT 2303, CHEMISTRY

PROJECT DESCRIPTION: Advances are sought in Air Force technological capabilities in structural and electronic materials, geo-environmental characterization, electromagnetic and conventional weaponry, electrochemical power systems and rocket propellant ingredients. Specific research emphasis is placed on the synthesis and characterization of higher performance, lower cost nonmetallic materials for application as structural composites, lubricants and sealants. A detailed description is sought of the atomic level interfacial contamination responsible for limits in the performance of electronic devices. Also under investigation is the reaction chemistry of the upper atmosphere that controls the density of the ionosphere as well as the intensity and spectral distribution of infrared background radiation. These factors limit the reliability of radio communications and the sensitivity of satellite surveillance systems. Similar detailed investigations of molecular level energy release mechanisms foster advances in laser weapon technology.

GENERAL OBJECTIVES: Research in chemistry seeks the knowledge and understanding required to develop new structural and electro-optical materials as well as improved means to synthesize existing materials. Unique chemical approaches characterize polymeric and elastomeric materials, ceramics, glass, semiconductors, and composite structures. In other areas of research emphasis, investigation is made of the molecular level processes of energy absorption, redistribution, and emission. In the example of the controlled, deliberate release of stored chemical bond energy, application is found in rocket propellants and in explosives. In the example of exchanging chemical bond energy for another energy form (electricity or light), application is found in electrochemical power systems and in chemical lasers.

RESEARCH EFFORTS:

STRUCTURAL CHEMISTRY

This research encompasses selected programs in polymers, ceramics, glass and advanced composites. The polymer research focuses on ordered polymers and molecular composites, macromolecular ultrastructures and nonlinear optical polymers. The ceramic research addresses solution ceramics, ultrastructured ceramics, and chalcogenide glasses.

Objectives and Applications: Advanced ceramics and ceramic composites for structural, optical, and electromagnetic applications will be employed when reproducibility and reliability can be demonstrated. To achieve this goal, the research effort addresses control of ultrastructures, which are 100 to 1000 Angstroms in size, through chemical processing. This approach is being

applied to a wide range of new ceramic and glass materials with sol gel, micromorphology and other routes. One objective of the polymer program is to develop nonlinear and electro-optic polymers for optical computing, optical signal processing, and optical sensor protection. A second objective is to design new high performance polymers through macromolecular ultrastructure development. The emphasis is on polymer alloys and blends, where two nonprocessable polymers with excellent properties can be easily processed into a usable form with the best properties of each. Emphasis is also on ordered polymers. In the latter, rigid chain structures are synthesized that reinforce a matrix of flexible chain polymers at the molecular level or provide a new approach to multifunctional polymers with unique optical, semiconducting and mechanical properties for smart skins and other applications.

Relationship to Other Programs: The ordered polymer subtask is part of the corporate Air Force Ordered Polymers Program with the Polymer Branch of AFWAL/ML. The Defense Advanced Research Projects Agency (DARPA) invests in this program with AFOSR. The nonlinear optical (NLO) polymer program. DARPA and the US Army Center for Night Vision and Electro-optics also invest in and the Polymers Program is the basis for a new generation of optical and electro-optical devices being developed at Rome Air Development Center (RADC) and the AFWAL Avionics Laboratory. The AFWAL/ML Polymer Branch coinvests in NLO Ordered Polymers. The research in solution ceramics and ultrastructured ceramics and polymers is the foundation for the AFSC Project Forecast II PT-20 Task on Ultrastructured Materials and the SDIO/IST Task on Optical Glass and Macromolecular Materials. The ceramics research is affiliated with high temperature turbine materials programs at AFWAL. The ultrastructured ceramics approach has resulted in the processing of reproducible and homogeneous high temperature superconductors, which is now receiving funding from DARPA. The polymer blends research is cofunded with DARPA impact programs to transition the new materials to industrial programs.

Initiatives: An initiative will be started in FY 89 to develop sol gel electro-optics. Emphasis will be on the advances demonstrated by organic NLO polymer-sol gel glass and ceramic nanocomposites and ultrastructures demonstrated for second and third order nonlinear optical activities. The development of channel and other waveguide structures in gels by chemical processing will be emphasized. Some effort will also be focused on exploiting the near single crystal electro-optic properties demonstrated in sol gels.

ELECTROCHEMISTRY

The goals are to obtain a fundamental understanding of electrochemical electrode processes, electrode activation and catalysis, non-traditional electrolytes, and electroanalytical techniques. A detailed understanding is lacking of the mechanism of electrode-molecule interaction at the electrochemical interface and the processes that activate and could catalyze electrochemical power generation. New non-aqueous electrolytes are required to extend the range of potentials, currents and temperatures in electrochemical power devices. New electroanalytical techniques are necessary to characterize operating electrochemical devices. Opportunities exist in the areas of electrochemical kinetics, electrocatalysis, in-situ

and ex-situ surface analysis, laser surface activation, molten salts, and polymer electrolytes.

Objectives and Applications: The objective is to develop longer life, more reliable, higher energy density electrochemical power systems. Operational applications will include batteries and fuel cells in missiles, ground power, and space power.

Relationship to Other Agency Activities: Army: Army Research Office, Harry Diamond Research Laboratory, and Electronics Technology and Devices Laboratory; Navy: Office of Naval Research, Naval Research Laboratory, and Naval Surface Warfare Center; NASA Lewis Research Center; and DOE Lawrence Berkeley Laboratory.

SURFACE CHEMISTRY

This effort is concerned with understanding and improving metal, semiconductor, polymeric and ceramic materials performance in chemically demanding environments. Invariably, unique chemical behavior is induced at materials surfaces depending on the manner in which the surfaces are terminated. The structure and electronic nature of the interface relative to the bulk material determine how that material interacts with its environment. Demanding environments that are particularly important for future Air Force aerospace systems are energetic particles flux in the space environment; high fluence and high energy laser environments; reactive environments created for intentional materials modification; high temperature oxidizing, corrosive environments; and low temperature embrittling environments. Fundamental knowledge of how surfaces of electromagnetic materials, structural materials, and tribological materials interact with these demanding environments is critically important to the design of future aerospace systems. The solutions of several particularly important problems, corresponding to the research efforts below, are especially emphasized: (1) the creation and understanding of new surface modification chemistry for electromagnetic and optical surfaces; (2) understanding the effect of high temperature oxidizing environments on alloys, polymers and composites; (3) design and understanding of high temperature solid lubrication systems for ceramic substrates; and (4) understanding the effects of particle flux in the space environment on space surveillance vehicles and their missions.

Objectives and Applications:

a. Improved processing and characterization of electronic and electrooptic devices could have a profound influence on the Air Force's ability to conduct its surveillance, guidance, C3I, and electronic warfare functions. This surface chemistry research is directed toward chemical control and characterization of semiconductor surfaces, dielectric surfaces and optics thin films. Study, on an atomic scale, of the chemistry of electromagnetic surfaces and interfaces is conducted seeking new insights into mechanisms of etching, deposition, epitaxy, clustering, adhesion, degradation and catalysis. Correlations will be established between surface properties of electromagnetic materials and materials performance.

b. Environmentally resistant polymers, metals, ceramics and composites enhance the survivability of crew and aerospace systems. Understanding the mechanisms of materials interactions with hostile environments will provide a rational basis for developing and employing environmentally resistant materials. This surface chemistry research will identify and improve composition and microstructure of corrosion-resistant and oxidation resistant materials by relating surface composition and structure to materials properties.

c. Improved solid lubricants and bearings are essential to many aerospace systems, particularly those with heavily loaded elements subjected to high temperatures. This surface chemistry research is aimed at understanding and controlling the friction and wear produced by lubricant-substrate interactions, surface topography and tribochemistry by modeling atomic-scale mechanisms of solid-solid interactions in ceramic-lubricant systems.

d. Components of aerospace vehicles and space-based detectors must be protected from orbital, solar, laser and nuclear radiation damage which impairs their mission. This surface chemistry research seeks to determine fundamental mechanisms of radiation damage in aerospace materials and coatings. Not only do these radiations produce reactions leading to electrical and structural damage, but fluorescent radiation can also interfere with surveillance and targeting operations. The research stresses electronic and thermal mechanisms associated with macroscopic radiation damage and fluorescent emission produced by photons, electrons and energetic atoms and ions.

Relationship to Other Programs: The research effort for objective "d" above, Surface Reactions in the Space Environment, is partially funded by SDI through the Air Force Materials Laboratory, EM Materials and Survivability Division. The majority of the research funding is a joint University Research Initiative entitled "Surface Reactions in the Space Environment" at Vanderbilt University and Northwestern University

Initiative: An initiative in molecular mechanisms of solid lubrication in cooperation with the Air Force Materials Laboratory will provide the scientific basis to create solid lubricated ceramic bearing systems which are effective and chemically stable over a wide temperature range. A more detailed description of this initiative is contained in Section IV, Research Initiatives.

MATERIALS SYNTHESIS

This research is directed towards gaining a better understanding of the chemistry and developing new approaches to synthesize a wide variety of chemical substances, including organometallic and intermetallic compounds, perfluorocarbon ether and related monomers and polymers, and energetic oxidizers and polymeric binders for the next generation of propellants and explosives. Biotechnological approaches are being explored that will lead to the synthesis of starting materials for making thermally stable structural polymers, as well as the biotechnological degradation of environmentally hazardous chemicals.

Objectives and Applications: The synthesis of organopolysilanes, siloxanes and other organometallics is being emphasized because of the high interest by the Air Force in these materials as precursors for high strength fibers and ceramic matrix materials. Research on new fluorination techniques and the synthesis of a wide variety of polyfluorinated organometallics and highly branched perfluorocarbon ether monomers and polymers is paving the way for Air Force nonflammable, thermally stable fluids and lubricating materials of the future. Research in the energetics area involves new chemical synthesis of high energy compounds and is exploring improved routes to the synthesis of propellants and explosives with emphasis on thermochemical improvements of energetic oxidizers and burning rate modifiers, and chemical improvements in propellant ingredients.

Relationship to Other Programs: The organometallics and preceramics chemistry provides basic information for the ceramic processing program at AFWAL/ML. The polymers research is fully coordinated with fluids and lubricants exploratory research and development programs at AFWAL/ML and the exploratory research programs on propellants at AFAL and explosives at AFATL. The biotechnology work is closely coordinated with biosynthesis and biodegradation programs at AFWAL/ML and AFESC/Envionics. All the work included in this research effort complements, but does not duplicate, research done by the Army Research Office, the Office of Naval Research, and DARPA.

HIGH ENERGY DENSITY MATERIALS

Theoretical and experimental studies will be carried out to test the limits of metastability in energetic compounds. An FY 88 initiative considerably increased the level of effort in this area. Candidate molecules for novel propellant, energy-transfer, and lasing systems will be calculated and synthesized. These candidate molecules will be used in the Air Force Astronautics Laboratory 6.2 research program in high energy density matter. The program's progress will be assessed in 1991 to determine whether funding should be continued at the same level or increased or decreased.

Objectives And Applications: Large increases in performance for both liquid and solid propellant rocket propulsion systems would enable new space operational capabilities, such as single-stage-to-orbit missions. The versatility of the Air Force's rocket systems would be greatly enhanced.

Relationship to Other Programs: This AFOSR basic research program is closely coupled to the Air Force Astronautic Laboratory's 6.2 program. The AFOSR program is designed to provide the theoretical foundation and experimentation required to understand the limits of metastability of chemical systems.

THERMOCHEMICAL DECOMPOSITION

The thermochemical decomposition of TNT and other related nitroaromatic systems will be studied experimentally with electron paramagnetic resonance spectroscopy. The details of the decomposition mechanism will be determined. The findings will be fed into related experimental programs at Frank J. Seiler Research Laboratory and the Air Force Armament Test

Laboratory, where the decomposition of different classes of compounds are being studied.

Objectives and Applications: Detailed knowledge of explosives' decomposition mechanisms allows design of new munitions with greatly retarded decomposition characteristics. The lower decomposition rates of these new materials will allow for more effective and safer Air Force ordnance.

Relationship to Other Programs: The Army and Navy both maintain large programs in the design and testing of new explosives for a variety of applications. The Air Force program has been successful in providing some of the basic mechanistic decomposition data to these larger Army and Navy programs.

BORON COMBUSTION

A boron combustion model using the best available experimental and theoretical data is being assembled that will allow a state-of-the-art assessment of proposed systems using either elemental boron or boron additives to hydrocarbon fuel systems. New data is being obtained on elementary chemical reactions that occur on the surface of a boron particle. The completed model will be delivered to the Aeronautical Propulsion Laboratory of the Air Force Wright Aeronautical Laboratories to be used for future propulsion system assessments.

Objectives And Applications: The performance of air-breathing propulsion systems would be greatly enhanced, both on a volume and mass a basis, if boron could be burned efficiently. However, the lack of a reliable model of the elementary combustion mechanism of boron (in the presence of hydrocarbons) hampers the design of a combustor to efficiently burn boron. The model is essential to the study and designs of engines that burn boron, either as an additive or as the primary fuel.

Relationship To Other Programs: The Aeronautical Propulsion Laboratory has a 6.2 program to develop boron fuels that tends to increase and decrease every few years. This exercise will deliver a model that the laboratory can use to accurately assess the usefulness of attempting boron combustion in any particular air-breathing engine.

GAS-SURFACE INTERACTIONS

Theoretical and experimental work is being performed to study elementary etching processes that occur on silicon and other semiconductor surfaces. The gas-phase steps in these etching mechanisms are being fed into a surface chemistry program designed to study reactions of the etching species on surfaces. Theoretical work on these etching mechanisms will continue as part of the molecular dynamics program.

Objectives and Applications: A knowledge of the etching mechanisms that result from gas-phase molecules interacting with semiconductor surfaces is crucial to the design of important technological processes producing

electronic components. This basic study of how gas-phase molecules interact with the surface is designed to provide these mechanistic details.

Relationship to Other Programs: The gas-surface interactions studies are a useful complement to the surface reactivity studies being performed as part of the AFOSR surface chemistry task. The Army, the Navy, and the National Laboratories also maintain complementary research programs that are vital to semiconductor processing.

STATE-TO-STATE CHEMISTRY

Basic experimental and theoretical studies are being performed to determine the microscopic details of how chemical reactions actually occur. In one set of studies, reactants are prepared in specific rotational and vibrational states with specified kinetic energy, and then the reaction cross-sections to state-determined products are measured. These results are compared with the computationally-determined dynamic trajectories for the same reactions. Another set of experiments is allowing, for the first time, spectroscopic observation of molecular configurations near the transition state configuration on a real-time basis. These detailed experimental results can also be compared with specific molecular trajectories calculated for the same reactions.

Objectives and Applications: These state-of-the-art experiments and calculations allow detailed observation of a chemical reaction as it is taking place. The results will eventually impact every area of chemistry important to the Air Force, including energetic compound decomposition, synthesis, and reactions; surface interactions of Air Force systems with their environment; and materials useful for Air Force applications in electronics, optical systems, and structural components.

Relationship to Other Programs: The Army, Navy, and the National Science Foundation have research programs in the fundamentals of chemical reactions. Our program at AFOSR is at the cutting edge of science in this fundamental area of research.

CHEMICAL LASERS

Molecular and chemical processes pertinent to the development of new electronic transition chemical lasers are being studied. Chemical reactions which produce electronically excited species are investigated to determine reaction rate constants, photon yields, branching ratios, and quenching mechanisms. Atomic and molecular electronic states with promising spectroscopic features are examined to evaluate laser potential, particularly with respect to light output in the visible and near ultraviolet. Chemical excitation schemes involve direct chemical and photochemical pumping as well as energy transfer from metastable molecules. A decision gate in FY 89 will allow evaluation of the viability of two new systems which recently have been alleged to lase in the visible. Decision gates every two years after that will allow for timely evaluation of other promising candidate systems.

Objectives and Applications: These studies are relevant to the search for new or improved high energy lasers and other directed energy weapons. High energy lasers operating at shorter wavelengths offer the promise of high brightness and increased range for comparable optic size.

Relationship to Other Programs: This program is closely coupled to the Air Force Weapons Laboratory 6.2 and 6.3 programs as well as the Strategic Defense Initiative Organization/Innovative Science and Technology effort in electronic transition chemical lasers. The AFOSR program is aimed primarily at providing support for the basic phenomenology to ascertain the nature and behavior of intermediate chemical species involved in current and potential chemical lasers. The Navy is interested in blue-green lasers but does not concentrate on chemically pumped systems.

CHEMILUMINESCENT REACTIONS

Detailed kinetics of the reactions of important atmospheric species are investigated using flow tubes, ion cyclotron resonance and molecular beam electric resonance spectroscopy, and laser-induced fluorescence. Some emphasis is placed on reactions of atmospheric ions and clusters. Processes leading to the emission of infrared, visible, and ultraviolet light are especially important. This area will be enhanced in FY 89 due to an initiative in ultraviolet plumes.

Objectives and Applications: The spectrum of the airglow constitutes the baseline against which surveillance systems operate. The success of these systems relies on the ability to discriminate and identify the target type from false targets and from natural and man-made backgrounds. The studies in this effort are aimed at determining the molecular processes occurring in the natural and perturbed atmosphere as well as in rocket exhaust plumes.

Relationship to Other Programs: These studies are coupled with 6.2 and 6.3 efforts at the Air Force Astronautics Laboratory and the Air Force Geophysics Laboratory dealing with infrared and ultraviolet plume signatures, upper atmospheric composition and structure, and atmospheric radiance codes. These areas are also of great interest to the SDIO, and have great bearing on surveillance and the ability to track targets, so they are important for a large number of DOD systems.

Initiatives: In FY 89 a new program dealing with ultraviolet radiation mechanisms will be funded. This initiative is aimed at providing a sound fundamental data base for ultraviolet field observations by studying the formation and kinetic processes associated with molecular emissions from missile plumes, airglows, and auroras. Both experimental and theoretical work will be undertaken through a coordinated program involving the Air Force Geophysics Laboratory, Air Force Astronautics Laboratory, and extramural contracts.

REACTIONS IN SPACE ENVIRONMENT

Molecular kinetic processes associated with the appearance in low earth

orbit (LEO) of the "shuttle glow" phenomenon are being investigated at a fundamental level. Reactions which yield the chemiluminescent species responsible for the glow are being investigated, and a source of monoenergetic ground-state oxygen atoms at 5 electron-volt energy, comparable to the environment encountered by orbiting spacecraft, is used to investigate the interactions of various materials with the ambient LEO atmosphere.

Objectives and Applications: This program addresses the limits to sensitivity of surveillance and detection systems on spacecraft in LEO due to near field background clutter in the visible and infrared arising from interactions with ambient oxygen atoms. The reactivity of various materials subjected to the space environment also affects their structural, optical, and electronic integrity, durability, and lifetime.

Relationship to Other Programs: This research effort is directly related to 6.2 and 6.3 programs at the Air Force Geophysics Laboratory and the Air Force Wright Aeronautical Laboratories. There are related Air Force University Research Initiative programs at Vanderbilt University and Northwestern University. NASA is urgently concerned about material survivability in the LEO environment because of the planned Space Station. It is funding many efforts to develop oxygen atom sources and to study material interactions with them. SDIO also has several related programs that it is funding because of interest in the functioning of detectors in the LEO environment.

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D. PROJECT 2304, MATHEMATICS

PROJECT DESCRIPTION: The research in mathematics and computer sciences seeks to provide mathematical modeling, simulation, and control of complex systems and to provide analytical and computational methods to solve problems of critical importance to the Air Force. The topics include control of aerospace systems; models and computational tools for the design of aircraft, missiles, or other weapons; efficient production of large-scale, well-documented computer programs and software; communication and information theory; artificial intelligence in surveillance systems or independent weapons; reliability, availability, and maintainability; and the allocation of resources in logistics or operational activities using optimization theory and mathematical programming techniques.

GENERAL OBJECTIVE: The Air Force has a major and expanding investment in computational hardware and software for a broad variety of systems and applications, from embedded C³ "black-boxes" and software to computers and algorithms used for the design, simulation and evaluation of Air Force systems. The goal of the mathematics project is to conduct research that will lead to greatly enhanced technology in the models, methods, algorithms, hardware, and software environment for military applications. For example, the development of space-based weapons for satellite and antiballistic missile systems is dependent on the ability to greatly expand our current capabilities in the functional areas of target acquisition, pointing and tracking (APT) and large space structure control (LSS). Distributed parameter control research is intended to lead to control techniques and algorithmic implementations to solve the problems of control/structural dynamic interactions in the presence of stringent APT requirements. In computer science, emphasis is being placed on knowledge-based systems technology that can incorporate time-dependent issues such as occurs in a military operations planning environment. Parallel processing for both symbolic and numerical processing is the most promising method to achieve the computing performance levels needed for sophisticated expert systems in a real-time military environment and for realistic design and simulation of future systems. In applied mathematics, research is being undertaken to understand complex, nonlinear behavior contained in the modeling of fundamental aerospace technology applications, such as fluid turbulence, using both analytical and numerical tools. Research on new computational methods in statistics is using the computer as a tool to provide more accurate assessments of reliability and maintainability for components of Air Force systems.

RESEARCH EFFORTS:

MATHEMATICS OF DYNAMICS AND CONTROL

The goal of this research effort is to seek new mathematical methods for the control of complex systems. Applications include flight control for supermaneuverable tactical aircraft, control vibrations and shape of large space structures, control of fluid flow for aerospace vehicle design, and control of combustion processes. Research is directed toward distributed parameter control, robust control theory, control of nonlinear systems, and adaptive and stochastic control.

Objectives and Applications: New approximation techniques are needed that can be used to construct models for identification, control, and optimization of systems governed by partial differential equations, functional differential equations and integro-differential equations and to analyze these approximate models for potential benefits and limitations. Problems of convergence, rates of convergence and real time implementation will be studied to obtain an understanding of the errors introduced by approximate modeling. Investigations will be made in the areas of multivariable control systems dealing with uncertainty, robustness and sensitivity using frequency domain tools. Work will continue in the area of singular values and their use in determining stability margins. Innovative and effective methods are needed for designing nonlinear feedback control systems that involve the nonlinear plant dynamics of flight control. Robust adaptive methods for control of complex systems will be studied. New identification concepts applicable to nonlinear systems will be pursued to obtain systems models which closely correspond to the actual systems, this providing more reliable digital control designs, and producing algorithms for use in real time identification. Emerging transonic unsteady aerodynamic methods will be integrated with structural equations and active control systems to investigate aeroelastic response and flutter suppression for transonic flight. Research will be performed using the theory of operators and dynamical systems in Hilbert spaces. Topics include state space modeling of aeroelastic systems, large space structures and of optical devices, approximation of infinite dimensional systems and large-scale computing. These topics are intended to provide the control methodology needed for such systems as adaptive control of ultra-large arrays, flight control for supermaneuverable tactical aircraft and active control and vibration suppression for large-space structures and deformable mirrors. Finite difference, finite element, and modal techniques will be used to develop approximate models of distributed parameter models. Function errors, finite dimensional approximation theory, and functional analysis will be used to study the effects of model reduction for infinite dimensional systems. Frequency domain methods will be analyzed and applied to various models of distributed parameter control systems. Basic new mathematical models will be developed for describing, analyzing, and synthesizing controllers for general systems. Research is required to produce the methodology for identifying, controlling and designing flight vehicles, using existing or proposed subsystems and components, to meet overall system configuration and performance specifications, and for analyzing and testing the resulting flight vehicle designs. Effective computational schemes for solving problems in control theory related to

flight control will be developed.

Relationship to Other Programs: The research effort in Mathematics of Dynamics and Control is the largest research effort in mathematical control theory. It is closely coordinated with research efforts in mathematics at the Office of Naval Research and at the Army Research Office. Two research efforts under the University Research Initiative are closely coordinated with this effort: the center at the University of Maryland for Modeling and Control of Multibody Systems and the center at Brown University for Distributed Parameter Control.

Initiatives: The FY 89 Research Initiative in Interactive Flow Control is described in more detail in Part IV. The mathematical aspects of this initiative seek to develop the theory of the control of complex systems, both distributed and nonlinear, and to apply modern control theory to the control of complex systems, especially fluid flows and combustion processes. Research in fluid mechanics to develop models sufficient for control design will also be pursued.

COMPUTATIONAL MATHEMATICS

This research effort seeks mathematical methods and algorithms for the numerical solution of physical problems of interest to the Air Force. Applications include improved design capabilities for high-performance aircraft and design of hypersonic vehicles, as well as computational methods for the solution of a wide range of problems of interest to the Air Force, including modeling and simulation of nonlinear optics phenomena, fluid flow, combustion processes, and continuum mechanics. Research is directed at the numerical solution of partial differential equations, as well as supporting work in numerical linear algebra and computational methods for ordinary differential equations. Much of the recent work is targeted at methods suitable for parallel computing.

Objectives and Applications: Research is needed in numerical methods for initial and boundary value problems. The objective of this research is the development and analysis of numerical schemes for the solution of ordinary, partial and functional differential equations that describe such applications as flight vehicles, fluid flow, electronic device simulation, aerodynamics, elastic materials, and large flexible structures. The goal is the construction and understanding of improved algorithms for complex systems. Existing algorithms will be modified to be made more efficient on the emerging vector and parallel computer architectures. A more radical approach will also seek the development of entirely new algorithms to exploit any inherently parallel structure. In the case of scientific computing, use of the parallel architecture will be considered for each level of a numerical approximation of a mathematical model. Efficient algorithms for solving the computational linear algebra resulting from the discretization of systems of equations and from signal processing applications need to be explored. This is particularly critical to the simulations envisioned as part of the Unified Life-Cycle Engineering thrust. The ultimate goal is to obtain more efficient and robust methods for the solution of the algebraic equations which are the end product of most numerical methods. One objective is to exploit the special matrix structure

inherent in many discretization approaches. Future efforts must address the fundamental issue of how to develop solution techniques for the linear algebra which are well-suited for exploiting the emerging parallel processing architectures, numerical algorithms need to be examined. The computational structure of the objective is to consider approximate methods for problems from diverse applications as assembled in a complete algorithm, and to consider at the various levels of construction the impact of new and future parallel architectures for large-scale scientific computing. Thus, the full range of the approximation needs to be evaluated in this parallel computing environment so that new methods which optimize the allocation of computational tasks among a number of processors are available to exploit the novel architectures.

Relationship to Other Programs: This program is coordinated with other computational mathematics programs, particularly at DOE. The program at AFOSR is directed toward problems of fundamental interest to the Air Force, especially computational problems occurring in fluid and solid mechanics.

APPLIED ANALYSIS AND PHYSICAL MATHEMATICS

This research effort pursues mathematical models and their analysis in areas of significant interest to the Air Force, such as fluid dynamics, solid mechanics, electromagnetic wave propagation (including radar interpretation), nonlinear optics, and combustion. The goal is to develop mathematical models of physical phenomena, and the mathematical methods for their analysis, as well as to produce models sufficient for numerical computation. The payoffs include the ability to understand and model physical phenomena, such as nonlinear optics or turbulent flow, leading to methods for their simulation and control.

Objectives and Applications: Nonlinear equations, such as those for transonic flow, laser focusing, detonation, stability of shear flows, wave (both electromagnetic and acoustic) scattering interpretation, geometrically exact elasticity, VLSI devices, nonstandard viscoelastic media, non-Newtonian fluids and nerve conduction models, exhibit a spectrum of behavior for which effective mathematical understanding is either not available or is only beginning to emerge. The research emphasis is on both analytical and numerical tools that tackle these problems. In the computational area, the use of a priori asymptotic analysis to identify the nature and location of small intervals over which the solutions vary appreciably will aid in the development of appropriate solution schemes. In the analysis area, the distillation of the significant subproblems embedded in the original governing systems (i.e., Maxwell's or Navier Stokes equations) is still accomplished by a judicious application of scaling, asymptotics and distinguished limits. Thereafter the issue becomes one of form and substance. Questions of existence and uniqueness for wave scattering must be addressed before to any algorithms are written. The same is true for the descriptions of exotic materials (both nonlinearly elastic and viscoelastic). The nonlinear evolution equations of detonation, shear and transonic flows require identification of stationary or quasi-stationary states together with a stability analysis while bifurcation theory is being applied and extended to study the transition to chaotic behavior. The use of fractals to help elucidate the scales of structure in chaotic systems is

being explored. The bifurcation and fractal analysis is particularly prominent for the coherent nonlinear waves which contemporary models of laser focusing predict.

Relationship to Other Programs: Two "Analysis/Modeling" centers were started under the University Research Initiative and are currently active. One at the University of Arizona concentrates on nonlinear optics (with strong ties to AFWL) and turbulence modeling. The other at New York University (Courant Institute for Mathematical Sciences) concentrates on vortex dynamics and heterogeneous media (with ties to AFWAL). A sizable portion of the mathematics program at DARPA supports work in nonlinear dynamics and is managed by AFOSR.

Initiatives: The FY 89 Initiative in Inverse Scattering is described in more detail in Section IV. The goal of this initiative is to seek novel analytical and computational methods for solving realistic problems in inverse scattering using acoustic, electromagnetic, or elastic waves. This theory has applications in many areas, including non-destructive evaluation to determine the size and shape of flaws and low-observable technology.

MATHEMATICS OF OPTIMIZATION

The goal of this research effort is to seek mathematical methods and algorithms for the solution of large-scale optimization problems, such as those occurring in optimal resource allocation, optimal scheduling and routing, and structural optimization. The payoffs include the potential to produce optimal schedules for large-scale transportation and logistics networks which conserve resources and to design structures using lightweight, maximum strength structural components for aircraft. Research is directed at linear and nonlinear programming methods, especially those amenable to implementation on parallel computers.

Objectives and Applications: With the advent of geometric schemes for solving large linear programming problems in polynomial time, opportunities to apply these new fast algorithms to problems heretofore considered computationally intractable must be pursued. The possibility of extending these algorithms to convex programming problems will be explored. Advances in technology, for example in communications networks, computational images, and VLSI designs, have created a wealth of problems whose formulations involve thousands of variables. Even the fastest general purpose algorithms cannot cope with such large problems. Therefore special techniques are necessary to take advantage of the structure of some of these large problems so that it becomes possible to solve them. These techniques are being pursued in support of the computer-optimized design requirements of the Unified Life-Cycle Engineering thrust. Fast algorithms for nonsmooth optimization problems for application in a variety of control systems need to be developed. Progress in nonlinear programming will require study in the applications of sequential quadratic programming to a variety of large-scale optimization problems. Considerable research remains to be performed in the areas of globalization of algorithms and the proper techniques for handling inequality constraints. Aligning optimization problem areas with computer environments is necessary to exploit increasing

computational power; for example, the application of parallel or concurrent computing technologies to large-scale optimization problems. Development is needed in the area of stochastic programming. A statistical theory for stochastic programs where only limited information about the probability distribution of the parameters is known needs to be developed. Important in VLSI chip design and placement is the study of annealing algorithms to solve combinatorial optimization problems. Work on optimization problems arising from finite dimensional approximations of equations in infinite dimensions, such as those coming from discrete versions of optimal control problems, is another area of interest.

Relationship to Other Programs: This research effort supports basic research which is coordinated with the Military Airlift Command's (MAC) efforts to produce optimal scheduling algorithms for MAC applications. This program is also coordinated with the ONR's program in Operations Research.

Initiatives: The FY 89 Initiative in Parallel Algorithms for Optimization is described in more detail in Section IV. The goals of this initiative are to seek novel methods for solving large-scale optimization problems using parallel computing. Applications of these methods include large-scale scheduling and allocation problems encountered in the Air Force and structural optimization problems encountered in the design of aerospace vehicles.

FINITE MATHEMATICS

This research effort seeks models and methods for analysis of problems which are inherently discrete. Applications include modeling computer and communications networks, design of VLSI chips, frequency assignment, and battle management. Research is directed at graph theory, combinatorial mathematics, and other areas of discrete mathematics relevant to Air Force problems.

Objectives and Applications: The methods of graph theory, probability theory, and combinatorial analysis will be applied to the fault tolerant design of communication equipment and networks for command and control. Research on the anti-jamming problem will require the application of game theory, information theory, and algebraic coding theory. Numerous scheduling, search, and resource allocation problems of military importance can be formulated as discrete optimization problems. Research will be performed to determine computationally efficient algorithms for solving such problems. Computational complexity of the problems will be investigated and approximate algorithms will be sought for very large problems and problems for which no efficient exact method can be found. The following must be developed: networks and algorithms for very fast parallel computation, techniques for placement and routing so that the networks can be laid out on a chip, algorithms for physical processes such as mask construction so that the chip can be efficiently fabricated, methods for identifying and overcoming faults introduced during fabrication, and algorithms that are tolerant to transient faults during use. New methods in combinatorics, probabilistic analysis, asymptotic estimation, and theoretical computer science will be used. Research is needed to determine

new encoding/decoding algorithms of reduced complexity which can be implemented in VLSI.

Relationship to Other Programs: This research effort is closely coordinated with the new research program in mathematics at the National Security Agency (NSA), which shares an interest in discrete mathematics related to coding theory.

PROBABILITY AND STATISTICS

This research effort seeks to broaden and strengthen the basic research foundation of probability theory, stochastic processes, and statistical inference. This effort addresses models applicable to systems of considerable complexity and inference procedures that are computationally feasible, yet flexible enough to deal with departures from assumed models. In addition to supporting other areas of research, including stochastic control theory and signal processing, research in this field has applications to reliability analysis of complex systems and statistical designs for the analysis of massive amounts of data. Research is directed at stochastic processes, statistical methods for reliability analysis, and statistical design and data analysis.

Objectives and Applications: New stochastic cumulative damage models for the analysis and prediction of crack initiation and growth under laboratory and service conditions will be developed. We will further develop the area of optimal design of experiments to make available accurate and efficient methods of collecting data relevant to the study of fatigue and fracture and crack initiation and propagation. Inference capabilities for crack growth models will be considered. The reliability of devices with random strength operating under random environmental stress will be studied, and these studies will be extended to include more realistic assumptions for the functioning of complex structures. More realistic and robust structural reliability models and statistical methods for inference using these models will be investigated, including multistate (degradable) models. Effects of dependence of components and imperfect repair will be studied and applied to problems involving total system reliability, maintainability, availability, and survivability. The integration of these issues is at the heart of Unified Life-Cycle Engineering. Optimal maintenance and replacement models and algorithms for their implementation will be developed, as will accelerated life testing methods needed to compress test time in life testing experiments. Simulation techniques, using both experimental and computational methods, for problems in reliability, maintainability, survivability and vulnerability will be studied. Improved analyses of reliability growth and certification procedures for quality assurance will be pursued. Development of non-normal and nonparametric multivariate models and studies of robust estimation in linear models will be continued. Bayesian inference capabilities for system reliability to incorporate prior information and past experience into statistical analysis will be investigated. Work on optimal maintenance and replacement policies and the development of algorithms for their implementation, and on the development of realistic accelerated life testing methods needed to compress test time will be continued. Bayesian approaches to quality control and to reliability growth, to help monitor the improvement of reliability in

systems under development will be considered. Modern aerospace systems, such as those envisioned by SDI and Forecast II systems, the space-based ASAT space surveillance systems, need to interpret and act on data obtained in massive quantities from multiple sources. Statistical research into the effects of spatial and temporal dependencies and patterns in data will therefore be emphasized.

Relationship to Other Programs: Close liaison is maintained with Program Managers at AFOSR, the Army Research Office (ARO), the Office of Naval Research (ONR), and the National Science Foundation (NSF) to coordinate programs and avoid duplication. The primary support for research in statistical reliability is found at AFOSR.

SIGNAL PROCESSING AND COMMUNICATION

The goal of this task is to strengthen the basic mathematical research foundation for communications and signal processing and to derive improved methods and algorithms for computational signal processing. This strengthened foundation will lead to improved understanding of the performance characteristics of complex communications and signal processing systems upon which Air Force operations are becoming increasingly dependent.

Objectives and Applications: The objective is to develop and explore applications of fast and numerically robust algorithms for adaptive filtering in high speed data communications and in digital filtering. The approach of higher order crossings to the problem of signal detection will be further developed, as will robust nonlinear filtering and smoothing designs. Robust data compression algorithms will be improved. Autoregressive models for signal detection will be investigated. Optimal detection schemes and advanced spectral estimation algorithms for the real-time acquisition, detection, and demodulation of stochastic and spread spectrum signals need to be formulated. A technology for ultra-wideband signal processing needs to be developed. Graph theory, probability theory, and combinatorial analysis will be applied to the fault-tolerant design of communication equipment and networks for command and control. Models which can be used effectively to discover the best methods for reconfiguration and recovery after a fault is found need to be explored.

Relationship to Other Programs: Close liaison is maintained among Program Managers at AFOSR, the Army Research Office (ARO), the Office of Naval Research (ONR), and the National Science Foundation (NSF). The AFOSR program in signal processing and communication is directed toward the development of novel mathematical approaches and toward the solution of mathematical problems that arise in signal processing. Research in engineering aspects of signal processing find support in the other agencies.

COMPUTER SCIENCE

This research effort focuses on research in those areas of computer science relevant to scientific computing, especially computer architectures for parallel and concurrent computations. Research areas include computer

architectures, parallel computing environments, software engineering, and computational complexity. The goal of this effort is to improve computing capabilities to solve the wide variety of problems in scientific computation of vital importance to the Air Force.

Objectives and Applications: In the area of multiprocessor architectures, approaches toward parallel architectures will be considered at simulation and prototype levels. The architectures will be evaluated in part relative to their effectiveness when applied to problems in computational linear algebra that arise in the solution of ordinary and partial differential equations from the physical sciences or relative to their artificial intelligence applications. Methods for automatically generating English language text from information represented internally in the computer will be emphasized. For artificial intelligence applications, we want to develop advanced software and architectures for knowledge-based systems which will overcome fundamental limitations in current knowledge-based implementation, management and maintenance techniques. Methods leading to the development of software and hardware architectures to support efficient logic programming will be emphasized. Research in the area of advanced higher order programming languages and software engineering includes the development of efficient compilers, integrated programming environments, knowledge-based systems, and techniques/tools for life-cycle testing/verification/validation, quality measurement, and cost estimation. Tools for enhanced environments for programming multiprocessor systems will be pursued to provide run time monitoring and performance evaluation mechanisms. Research will be emphasized in data base management systems, distributed data bases, high level user interfaces, data format linkages, inferential rules for intelligence data bases, and any other pertinent technical considerations which impact the processing of data in an accurate and timely manner.

Relationship to Other Programs: This work is closely coordinated with computer science work at DARPA. Also, work in this area is coordinated with other agencies through the Federal Coordinating Committee for Science Engineering and Technology (FCCSET). Also a program in parallel computing environments started at the University of Illinois under the University Research Initiative and managed by AFOSR is closely tied to this research effort.

ARTIFICIAL INTELLIGENCE (AI)

This research effort addresses fundamental questions in artificial intelligence. The ability to store information in a form suitable for a computer program to take action as a consequence of this information, provides us with the means to design intelligent computer systems. Expert systems, machine vision systems, and speech understanding systems are examples of such systems--they reason about their course of action based upon information available to them. This effort seeks the basic knowledge required for such systems and includes work in expert systems, automated vision, speech understanding, and neural networks.

Objectives and Applications: Paradigms that allow an expert system to learn from experience and thus automatically add new knowledge to its knowledge

base will be investigated. Generic tasks such as classification (useful in diagnostic reasoning), state abstraction (useful in answering questions of the type, "what will happen if [action] is taken on the system"), "intelligent" information passing (useful in certain kinds of data retrieval problems), and hierarchical plan refinement (useful in certain types of design problems) together with the appropriate knowledge representation and control strategies should be pursued. Paradigms to characterize systems that represent and reason about their own beliefs, to represent the basic concepts such as time, space, or knowledge, and the way these concepts are conveyed in natural language in a form amenable to computational manipulation and automated inference, to exploit inherent parallelism whether by making parallel existing sequential codes by mappings to the physical architecture or by developing entirely new logical paradigms, etc., will be investigated. Domain independent and, if possible, parallel paradigms for automatically generating a sequence of steps for achieving some stated goal including a formalism for representing domains, and dealing with constraints will be considered. For example, the representation of constraints might include knowledge of a constraint's importance, its sphere of relevance, its interdependencies with other constraints and the possible ways in which it can be relaxed if it cannot be satisfied, including an indication of the relative preferences among the alternatives. Image understanding paradigms with special attention to parallel algorithms used to process the image and to the design of expert systems for understanding the image will be studied. At the conceptual level a paradigm might involve the transformation of the image data into an abstract internal representation of the visible objects in the scene using cues like color, texture, shape, or motion, expectations about general classes of scenes, etc. Approaches to handling the uncertainty in the results of measurements and transformation, such as the Shafer-Dempster theory of evidence, would seem appropriate in this context. Biologically based paradigms for AI will be investigated. To some extent the growing understanding of the functioning of the brain, eye, etc., can aid in formulating such paradigms. For example, image understanding paradigms involving interpretation of image contours or texture changes have benefited from a knowledge of what information is made explicit in human vision and what processes subserve the extraction of that information, resulting in a representation of the image with appropriately reduced information content. Alternatively, the interconnection architecture of neurons in living systems is being explored using experimental data from neuroanatomy, neurophysiology, psychology etc., to induce the principles and mechanisms by which the brain functions.

Relationship to Other Programs: This effort is related to DARPA and the Office of Naval Research (ONR) supported projects in Machine Learning, Qualitative Reasoning, and Natural Language Understanding. AFOSR and DARPA jointly support projects in Case-Based Reasoning, Formal Geometric Reasoning, Intelligent Distributed Systems, and Motion Detection in programs managed by AFOSR.

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E. PROJECT 2305, ELECTRONICS

1. PROJECT DESCRIPTION: Electronics research provides fundamental knowledge required to advance Air Force capabilities in Brilliant Weapons, Special Operations, Tactical Reconnaissance and Intelligence, Electronic Combat and Tactical Warfare. Research topics include optical signal processing for target recognition and terminal guidance, semiconductor devices for high speed digital and analog signal processing, and microwave and millimeter wave signal and power generation, electromagnetic propagation, antennas, target signatures, microwave tube science, superconducting analog signal processing, robust communications techniques for command and control, and nuclear radiation hardening of electronic circuits and devices.

2. GENERAL OBJECTIVES: The Air Force electronics research program strives to provide the fundamental basis for developing future generations of electronic devices and systems that impact on new Air Force technologies such as Battle Information Management Systems, Integrated Photonics, Smart Skins or Nonlinear Optics. Research in this program is concerned with the understanding of fundamental principles which govern electronic processes such as signal propagation, data processing, radar ranging and resolution and radiation hardness. The understanding of these principles will enable the engineer to model and predict performance of electronic devices and systems. For this reason, research in physical electronics including ultra submicron electronics, antennas and propagation, and analog (optical, superconductive) and digital signal processing is strongly emphasized. In recent years, the traditional emphasis in defense research has been tempered by an equal emphasis on reliability, affordability, and long-term supportability of end-use systems. Even though not specifically stressed, it must be borne in mind that to be practical, new developments and new technologies must be compatible with these requirements which have an important bearing on logistics issues. It is the intent of this program to encourage innovation in areas in which deficiencies in the present technology base have been recognized. Electronics is a rapidly progressing field. Recognizing that the commercial electronics industry performs massive research and development, the Air Force program in electronics predominantly emphasizes research on those technologies for which no significant commercial market can be foreseen at this time or where support of basic research will greatly accelerate progress in technologies important to the Air Force.

JOINT SERVICES ELECTRONICS PROGRAM

The Joint Services Electronics Program (JSEP) is a mutual Army, Navy, and Air Force enterprise designed to provide the Department of Defense with a university-based research capability in the electronics sciences and related

areas. The chief objective of JSEP is to support relevant research in the member universities that they may contribute to the military electronics technology base to complement research programs in which directed efforts are made to solve military electronics problems.

Objectives and Applications: Four principal areas of research are sponsored: solid state electronic materials and devices, electromagnetics, quantum electronics, and information electronics. Each of the 12 current major universities involved in the program carry on efforts in one or more of these areas, often in several of the areas. The particular balance between the research areas at a given institution depends upon a number of factors, including the relative strengths of faculty and facilities available to the program.

Relationship to Other Programs: Because JSEP is a tri-service funded and managed program, it provides a natural and effective mechanism for the coordination of electronics related research activities for the Department of Defense. In addition to personnel from the service basic research offices, a large number of DOD laboratory specialists are involved in proposal evaluation and in the tri-annual on-site reviews. By this means, the DOD laboratory community also is kept abreast of a wide range of university electronics research. Contacts between university and DOD personnel made in the review process frequently lead to cooperative research ventures. One of the innovative aspects of JSEP is the provision for the funding of more speculative research ideas. In many instances, after proof-of-concept research has been performed with JSEP funding, the work is carried on with more traditional and expanded funding sources. Nearly every JSEP institution has several such active follow-on programs at any time. Several of the institutions have been successful applicants for special programs, such as the University Research Instrumentation Program and the University Research Initiative.

Initiatives: As described above, JSEP encompasses a broad spectrum of electronics related research. Consequently, JSEP sponsored research is often closely related to initiatives and other special focus programs of the services. Most recently, JSEP research efforts have helped to spawn such AFOSR initiatives as Monolithic Millimeter Wave Integrated Circuits and Wafer Level Union.

ELECTRONIC DEVICES

This research program encompasses a wide variety of advanced electronic structures and devices. The medium in which these devices are fabricated is primarily semiconductors, most often compound semiconductors such as gallium arsenide, indium phosphide, and related ternary alloys such as aluminum gallium arsenide. The quest for advances in electronics devices requires efforts in theory and modeling, computer assisted design (CAD), fabrication and testing.

Objectives and Applications: Specific devices currently being explored include the high electron mobility field effect transistor (HEMT), the heterojunction bipolar transistor (HBT), resonant tunneling structures and various types of superlattices. Research also is being pursued in

superconducting electronics, both with the traditional cryogenic materials and using the newer high temperature superconductors. These devices, when perfected will find broad application to many Air Force electronic systems. A common feature of many of the research projects is the inclusion of quantum mechanical effects, both incidental and deliberate.

Relationship to Other Programs: Substantial cooperation exists both within and outside of the Air Force's basic research program in electronic devices. There is substantial, carefully planned overlap with the Joint Services Electronics Program (see separate text). Air Force laboratory in-house research programs are tied into other laboratory research when appropriate. Many significant accomplishments have resulted from such collaboration. There are joint projects underway involving, for example, Small Business Research Initiative projects and AFOSR core research. The AFOSR University Research Initiative center at the University of Rochester is actively engaged in several collaborations with other Air Force electronics projects.

Initiatives: The AFOSR initiative in Monolithic Millimeter Wave Integrated Circuits is now coming to a close. Taking its place is a Project Forecast II inspired initiative entitled Wafer Level Union. The new initiative with this title will concentrate on the basic materials science of selective area heteroepitaxy. The development of this capability will enable such monolithic integrated systems as phased array radar and integrated opto-electronics for fiber optics communications. A new initiative is currently being planned in quantum transport and will deal with structures incorporating quantum mechanical design features.

OPTICAL ELECTRONICS

This research is concerned with the eventual development of devices for optical computing architectures.

Objectives and Applications: The primary goal of this research is to understand the proper kinds of devices to be used in optical computing architectures. This requires the development of methodologies for the successful integration of materials and devices with the top-down guidance of computationally competitive architectures. The devices considered will be high speed, low energy, and robust, with gain and memory and easily configured into arrays. The understanding of the fundamental limits of the interaction of light with materials is crucial. Semiconductor technology with engineered materials will be used whenever possible and appropriate. This will lead to "building block" components that can be used in a number of different optical devices.

Relationship to Other Programs: Optical architectures will give the top-down guidance necessary for appropriate and useful device design. This program relates to more applied research programs at RADC, DARPA/DSO and SDIO/Office of Naval Research (ONR) and is closely coordinated with those programs. Joint fundings of some of these efforts exists at RADC and DARPA/DSO. Industry IR&D reports are evaluated and annual IR&D on-site reviews of relevant work are attended. Also, a University Research Initiative has been established at the University of Southern California

for the integration of optical computing architectures and devices.

Initiatives: No initiatives in FY 89.

ELECTRICAL AND OPTICAL SYSTEMS

This research is concerned with the eventual development of massively parallel computers which will be used in Air Force problems such as smart munitions, electronic warfare and artificial intelligence.

Objectives and Applications: This research provides the fundamental knowledge necessary for the proper use of optics in computing and processing. Focus is on appropriate choice of problem class for optical architectures and the design of these optical architectures using existing and future projected devices. The computational advantages and the proper use of parallelism in optics guide both architectures and device development. This would eventually lead to both hybrid and novel optical computing machines. Current systems being investigated are optical inference engines, optical neurocomputers, and optical digital computers. This technology will find application in situations requiring extremely fast and efficient computation. Another goal of this research is to understand and extract the computational principles behind biological brains and to eventually use this knowledge to build neurocomputers. The focus is on understanding the computational primitives and organizational principles underlying biological intelligence, the appropriate problems for these systems to solve, and how this knowledge is to be mapped into an appropriate technology. The eventual goal will be to build brain-like computers. Air Force applications of this research would be in smart munitions, intelligence pilot assistance, robotics, intelligent logistics, and surveillance.

Relationship to Other Programs: This research effort is related closely to the Optical Electronics research effort, where the basic concern is the eventual development of arrays of high speed, low energy, adaptive optical devices with gain and memory. These devices will then be used in the optical architectures discussed earlier. This program relates to more applied research programs at RADC, DARPA/DSO and SDIO/Office of Naval Research (ONR) and is closely coordinated with those programs. Joint funding exists for some of these efforts with RADC and DARPA/DSO. Industry IR&D reports are evaluated and annual IR&D on-site reviews of relevant work are attended. Also, a URI has been established at USC for the integration of optical computing architectures and devices.

Initiatives: No initiatives in FY 89.

ANTENNAS AND PROPAGATION

This research is concerned with radar systems and radar target identification and location.

Objectives and Applications: The basic objective of the research effort is to understand and model the transmission, propagation, and scattering of electromagnetic signals. Emphasis is placed on the development of

appropriate mathematical and physical models for the propagation and scattering of electromagnetic radiation. Also major emphasis is on printed-circuit antennas, adaptive beam steering, novel particle beam antennas, ionosphere propagation, and target and cluster scattering models. Applications include radar system design, signal processing, target tracking and identification and surveillance.

Relationship to Other Programs: This program is performed entirely at RADC. Industry IR&D reports are evaluated and annual IR&D on-site reviews of relevant work are attended.

Initiatives: No initiatives in FY 89.

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F. PROJECT 2306, MATERIALS

1. PROJECT DESCRIPTION: The materials research project provides the knowledge required for improving the performance, cost, and reliability of structural and electronic materials. This project supports the Air Force S&T Programs in Strategic Offense and Defense, Tactical Warfare, War Reserve Material and Air Base Survivability, Mobility and Reliability, Maintainability and Producibility. Specifically, direct contributions to the NASP, High Performance Turbine Engine, Hypersonic Glide Vehicle and Unified Life Cycle Engineering are planned for the structural materials program, while major advances in electronics related technologies (discussed in Project 2305) are predicted for the electronic material part.

2. GENERAL OBJECTIVES: The materials research program provides the knowledge for improving the performance, cost, and reliability of structural and electronic materials. The structural materials research program studies a broad range of material properties, such as strength, toughness, fatigue resistance, and corrosion resistance of airframe, turbine engine, and spacecraft materials. Emphasis is on titanium, aluminum, magnesium, niobium and nickel-based alloys, metal and ceramic matrix composites and ceramics. Research in new processing methods and nondestructive evaluation of these materials complements research on materials properties. The electronic materials research program is concerned with semiconductor, optical and magnetic materials used in avionics, surveillance, communications, guidance, and electronic warfare. Emphasis is on compound semiconductors, superconductors, materials for infrared fiber optic systems and nonlinear optical materials for signal processors.

Structural materials in use today are operating at or near their capacity in terms of stress, temperature, and environment. Yet, it is necessary to prolong use of current systems, and to satisfy new demands for lighter-weight structures of extreme reliability and resistance to environmental attack or sudden failure. This goal can be attained by understanding the principles that govern properties and material behavior as a function of microstructural features, composition, and processing parameters. Failures such as creep, fatigue and fracture are directly related to the microstructures of materials. Understanding these processes and the governing mechanisms must be integrated with appropriate macroscopic descriptions.

Electronic materials encompass a broad spectrum of research objectives that relate to the synthesis, preparation, characterization and analysis of electronic materials. These efforts normally include a detailed

understanding and control of material purification, film and crystal growth, defect structure, selective and controlled doping, and related processes and phenomena. The materials are generally in the condensed state, either crystalline or amorphous in form. In view of their potential impact on new and improved electronic and electrooptic components and aerospace systems, improved understanding of the basic mechanisms responsible for their semiconducting, optical, thermal, acoustic, magnetic, superconducting and insulating properties is needed as a foundation for the evolution of novel and advanced device concepts. Devices using the special properties and characteristics of advanced materials, will have a profound influence on the Air Force's ability to carry out its reconnaissance and surveillance, navigation and guidance, command, communication, control and intelligence and electronic warfare responsibilities and functions.

3. RESEARCH EFFORTS

METALLIC MATERIALS

This research is concerned with advanced metals, alloys, intermetallics and metal matrix composites for engine, airframe and spacecraft structural (load-bearing) materials.

Objectives and Applications: This research provides the fundamental knowledge required for creating, synthesizing, and improving metals and alloys for aerospace applications. Specific tasks in this research effort are Metallurgy of Structural Materials, Hybrid Materials, Computational Materials Science, High Temperature Materials, and Metal Matrix Composites. Investigations are aimed at understanding the behavior of materials at ambient and elevated temperatures. Such behavior includes strengthening mechanisms, phase transformations, plasticity, creep, fatigue, environmental effects, and dynamic and static fracture. Understanding the relationships among alloy chemistry, micro/macro structure, material processing, and mechanical behavior are essential aspects of this program. Individual research programs address alloys with high specific strength (aluminum, titanium, magnesium), high stiffness (metal matrix composites), and high temperature capability (titanium, superalloys, refractory and ordered alloys).

Relationship to Other Programs: This research effort relates to Materials Synthesis (alloy design, metal matrix composites), Processing Science (rapid solidification, superplasticity), and Materials Behavior (fatigue, deformation, creep, fracture). This work is being done on materials for engines (Titanium, Nickel, Niobium alloys and metal matrix composites) and airframes (Aluminum, Titanium, Magnesium alloys and metal matrix composites). Much of the research is applicable to spacecraft. The research is coordinated with complementary efforts of the Army Research Office (ARO), the Office of Naval Research (ONR), NASA and the National Science Foundation. A complementary program on refractory alloys is managed by AFOSR although funded by DARPA. Industry IR&D reports are evaluated and annual IR&D on-site reviews of appropriate companies are attended. A University Research Initiative has been formed at Carnegie-Mellon University on High Temperature Metal Matrix Composites.

Initiatives: A FY 89 Initiative on Computational Materials Science is described in section IV. The effort will involve interdisciplinary research in materials science, physics, processing science, and computer science and is driven by recent advances in the theoretical, computational experimental tools available to materials scientists. The program is a joint AFOSR/NE and AFWAL/MLLM effort. AFOSR efforts will focus on ab initio calculations, modeling, and simulations of microstructure, controlled experimental verification, and approaches to synthesis of new material systems. AFWAL/MLLM efforts will focus on an alternative to experimentally determining the property and alloying behavior of materials, i.e., to apply the advanced methods of computational physics to model their behavior and to compute their properties.

NONMETALLIC MATERIALS

This research is concerned with advanced non-metallic materials, including ceramics, ceramic matrix composites, carbon-carbon composites and cementitious materials for engine and spacecraft structural (local bearing) materials, and for ground structures.

Objectives and Applications: Interest in nonmetallic structural materials is driven by a broad range of technological needs. The desire to create stoichiometric gas turbine engines, hypersonic transatmospheric space planes, and highly efficient space-based power systems calls for research in high temperature oxidation resistant load-bearing materials. Materials with ionic and covalent bonding have higher binding energies than metals and therefore materials such as carbon, borides, oxides, nitrides, and carbides will offer the required high temperature. Specific tasks in this research effort are Nonmetallic Structural Materials, High Temperature Ceramic Composites, Nozzle Materials Technology, and Pavement Materials. The objectives of this task are to address the barriers preventing widespread use of nonmetallic materials in high temperature structural applications--namely, lack of toughness, susceptibility to oxidation, synthesis, and processing difficulties. Funded research emphasizes the establishment of microstructure property relationships; however, innovative atomistic approaches which seek to understand the nature of brittleness will also be considered. Transformation toughening is a major theme of this task. Another method of toughening brittle materials is to reinforce a brittle matrix with a second phase in the form of whiskers or fibers. Such composite materials fabricated from epoxy reinforced with graphite fibers are now used successfully on aircraft structures. Fundamental research is being conducted on composites fabricated with advanced ceramic and cement matrices to establish principles of design for such hybrid materials. Other potential toughening mechanisms are being explored.

Relationship to Other Programs: This research is coordinated with complementary efforts of the Army Research Office, the Office of Naval Research, NASA, and the National Science Foundation. A complementary DARPA funded program on ceramic matrix composites is managed by AFOSR. Industry IR&D reports are evaluated and annual IR&D on-site reviews of appropriate companies are attended. A University Research Initiative (URI) has been formed at University of Illinois on Cementitious Materials.

PROCESSING AND MANUFACTURING SCIENCES AND EVALUATION

This research is concerned with efficient and effective obtaining of a wide spectrum of advanced materials for aerospace applications. Processing and manufacturing processes to obtain required materials under cost-effective, timely and high quality control conditions are prime concerns.

Objectives and Applications: Specific tasks in this research effort are Nondestructive Evaluation (NDE), NDE Technology, Processing Fundamentals, and Manufacturing Science. Nondestructive evaluation and NDE technology refer to the flaw-seeking inspection of weapons system components. A variety of probe methods are used, including acoustic and ultrasonic elastic waves and electromagnetic radiation from x-rays through the visible to the millimeter wavelengths. The interaction of these probes with metals, ceramic, and composite materials is studied to improve the resolution and accuracy of flaw detection. It is envisioned that nondestructive evaluation sensors will be used in conjunction with proximity sensors and vision systems in future automated manufacturing facilities. Processing fundamentals are used to develop analytical models for describing material behavior and describing metal flow for 3-D nonaxisymmetric structures, as well as to develop processing microstructure maps for controlling microstructure development and defect generation during deformation. Output from these efforts is also used to develop a structure of related elements and tools for building an expert system that consults with a user on the appropriate use of analytical simulation methods for the design and control of metalworking processes. Manufacturing science activities include: (1) intelligent robotics investigations to establish new concepts and approaches to provide nonlinear, adaptive control; to establish capabilities to provide artificial intelligence approaches for both planning and obstacle avoidance; to significantly advance the capability for computer-based object recognition; to discover techniques to permit direct control from computer-based design data; and to create innovative approaches for automated discrete part assembly, (2) expert systems for guiding the analysis of metalworking processes to develop a structure of related elements and tools for building an expert system that consults with a user on the appropriate use of analytical simulation methods for the design and control of metalworking processes, (3) innovative utilizations of artificial intelligence in NDE and in-process control.

Relationship to Other Programs: This research is coordinated and complementary with efforts at the Army Research Office (ARO), the Office of Naval Research (ONR), NASA, the National Science Foundation, and DARPA. Industry IR&D reports are evaluated and annual IR&D on-site reviews of appropriate companies are attended.

Initiatives: No FY 89 initiatives are included in this research effort.

ELECTRONIC MATERIALS

This research is directed toward developing the electronic materials used in Air Force electronic devices and systems. Several classes of materials are under investigation including semiconductors, superconductors and optical films. Research has progressed from the traditional niobium based

superconductors and traditional semiconductors to include the recent high temperature superconductors and other new classes of semiconductors. We continue to seek materials permitting higher performance electronic and photonic systems.

Objectives and Applications: Air Force electronic and electrooptic signal processing, communications, and electronic warfare systems require continuing improvements in capabilities. This research seeks the fundamental knowledge required for the growth and utilization of electronic materials and structures. No single electronic material has the combination of properties required for all applications, so several classes of semiconducting materials are under investigation. Semiconductors, such as gallium arsenide or indium phosphide, provide the electronic and optoelectronic properties necessary for advanced signal processing applications and for optoelectronic communications. These materials are under investigation for potential uses in infrared and ultraviolet detectors and for use in infrared active electrooptic countermeasures. An effort aimed at developing a silicon heterostructure technology for the next generation computing requirements has begun this year. Overall, emphasis is placed on combining materials science with solid state physics to investigate the growth, defects, and properties of multilayer semiconductor structures.

Relationship to Other Programs: A close relationship exists with other research efforts concentrating on devices. Specifically, physical electronics devices rely on the materials investigated here to fabricate the advanced electronic devices. Optical computing devices will make similar use of these materials for optical and optoelectronic switching devices. Air Force laboratory applied research programs in millimeter wave devices and optoelectronic devices rely on the materials technology. Forecast II Project Technologies PT-40 (Ultra-Structured Materials) and PT-12 (Ultra-Resolution Sensors) expand upon aspects of this research effort.

Initiatives: No FY 89 initiatives are included in this research effort; however, the Wafer Level Union FY 89 initiative draws on the fundamental and general research from this program. It differs in that the focus of Wafer Level Union is on the selective epitaxy of gallium arsenide on silicon, while the relevant portions of this research effort concentrate on the fundamentals of lowering processing temperatures and heteroepitaxy.

OPTICAL FILMS AND SUBSTRATES

As high power and other optical systems make their way into the Air Force arsenal, the necessity of understanding the limitations of the components of these optical systems increases. This research is directed toward understanding and improving two of these components--the lenses and mirrors controlling the light paths and the films coating the lenses and mirrors to eliminate losses.

Objectives and Applications: The performance of many optical systems are limited by failures of the optical reflection or anti-reflection films, and by background scatter from films and substrates. This effort aims to increase system performance by seeking the fundamental knowledge required

for improving the properties of the optical films and substrates used in the Air Force's optical systems. A two-fold approach is taken. The polishing and grinding of optical substrates is investigated with the goal of understanding the micromechanics of fracture and the chemo-mechanical effects which are caused by polishing. The optical scatter from the resulting surfaces is studied as a function of the grinding and polishing process. The second approach involves the laser damage threshold of optical films. Films deposited under carefully controlled, ultra-high vacuum conditions are evaluated for their optical and structural properties. The relationship between the microstructure of the resulting film and the optical properties, and the optical laser damage threshold is characterized from a firm scientific foundation.

Relationship to Other Programs: A close relationship exists with other research efforts, concentrating on optical films and substrates; specifically, a University Research Initiative at The University of Arizona in Tucson, and fundamental investigation of film deposition, in general, investigated in the electronic materials research effort. Much of the substrate work is included in the DOE laser fusion programs.

Initiatives: No FY 89 initiatives are included in this research effort.

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G. PROJECT 2307, FLUID MECHANICS

1. PROJECT DESCRIPTION: Air Force basic research in fluid mechanics seeks to understand key fluid flow phenomena, to devise improved theoretical models for aerodynamic prediction and design based on that understanding, and to originate flow control concepts that will expand current flight performance boundaries. The research seeks to illuminate the behavior and governing mechanisms of complex flow fields associated with aerospace vehicles configurations and flight regimes of importance to the Air Force.

Research on External Aerodynamics emphasizes the development of computational methods for accurate and efficient numerical solution of the partial differential equations of fluid dynamics, including methods for predicting real gas effects in hypersonic flows. Turbulence Structure and Control research focuses on the role of turbulence in the prediction and control of shear flows, including those which govern flight vehicle aerodynamics and the performance of gas dynamic lasers. Research on Unsteady and Separated Flows addresses the dynamics of separating unsteady flows driven by large amplitude body motions, such as those occurring in rapid dynamic maneuvers. Research on Internal Flows seeks to understand the complex internal flow environment of gas turbine engines, including heat transfer phenomena and turbomachinery instabilities.

This project supports Project Forecast II technology and systems thrusts in High Performance Turbine Engines, Combined Cycle Engines, STOL/STOVL/VTOL (S-short, T-take, O-off; L-landing, V-vertical), Hypersonic Performance, Supersonic V/STOL Tactical Aircraft, and the Advanced Aerospace Plane.

2. GENERAL OBJECTIVE: The overall objective is to provide the foundation of basic fluid mechanics knowledge that is essential to the development of the advanced aerospace vehicles and systems for the Air Force. Future Air Force mission requirements supported include the capability to maneuver in the post-stall flight regime, to operate from shortened or damaged runways, to cruise at hypersonic speeds, and improved maintainability and efficiency.

3. RESEARCH EFFORTS:

EXTERNAL AERODYNAMICS

Computational methods for the prediction of complex flows will be developed using methods suitable for use on the most powerful vector computers. The possibility of exploiting increased parallelism in future computer configurations will be explored. Better procedures for error estimation and more accurate and reliable computation for major solution techniques will be pursued. These techniques include multigrid procedures, solution adaptive

grid techniques, and the use of unstructured grids and automatic coordinate generation for complex flow configurations. Novel techniques such as the multisurface coordinate transformation scheme, variants of the body-fitted coordinate scheme, and other algebraic and geometric ideas will be pursued. Additional problems which must be solved include the correct formulation of well-posed and stable subsonic boundary conditions; development of efficient, time accurate algorithms for unsteady viscous flows; and procedures for solution-driven adaptive grids. Work will also address the coupling of the equations of fluid dynamics with the equations for elastic structures, flight mechanics, and real gas chemical kinetics.

Strong shock wave interactions with turbulent boundary layers will be studied experimentally and computationally, including the recovery of turbulent boundary structure downstream of the interaction. Theoretical and numerical analyses of the transition process in hypersonic boundary layers will be conducted. At present no viable techniques exist for predicting transition in this flight regime. The characteristics of turbulent boundary layers in hypersonic flows will be studied experimentally, including the effects of nose tip bluntness. The characteristics of supersonic flow past sharp-edged delta wings will be explored. Several approaches for numerically modelling viscous-inviscid interactions will be pursued.

Objectives and Applications: This research seeks to devise computational techniques for solving numerically the partial differential equations of fluid dynamics in an efficient, stable, and accurate fashion. It also seeks to develop an understanding of the dynamics of shock wave/turbulent boundary layer interactions and the recovery of boundary layer structure downstream of these interactions. In addition, this research will develop an understanding of hypersonic boundary layer flows, including real gas effects and the transition from laminar to turbulent flow. It will provide computational analysis tools which, in the absence of adequate ground test facilities, are necessary for the development of sustained hypersonic flight vehicles.

Revolutionary opportunities for advancing flow prediction capability will develop from new generations of parallel computer architectures. Exploration of lattice gas and other methods for parallel computing is planned for an initiative in FY 91.

Multi-body codes are required for application to programs such as the SDIO Advanced Launch System. An important technology needed by the X-29 program is the capability to evaluate unsteady inlet design concepts. Real gas codes and codes for supersonic combustion prediction are needed for the X-30 program, as is basic data for laminar to turbulent transition in hypersonic boundary layers and new concepts for controlled mixing in supersonic combustion ramjet propulsion systems. This research will contribute directly to these essential programs.

Relationship to Other Programs: This research effort supports, in collaboration with the Office of Naval Research (ONR) and NASA, a Hypersonics Research and Training program administered by NASA. This program seeks to provide education and training in hypersonics as well as basic research at six university centers.

TURBULENCE STRUCTURE AND CONTROL

This research effort largely consists of experimental research on the nature of organized, coherent motions in both boundary layer and free shear flows. The process of transition from laminar to turbulent flow in boundary layers and free shear layers is studied using experimental, theoretical, and computational approaches, including full numerical simulation of the Navier Stokes Equations. A key issue is to sort out the influence of freestream and background disturbances on the location of transition. Experiments also examine the mechanisms responsible for production and regeneration of turbulence in fully developed boundary layers and free shear layers. Increasing emphasis is being placed on the influences of pressure gradient, compressibility, and flow curvature. New experimental techniques are being developed using laser fluorescence and automated image enhancement and processing to provide the capability for future experiments to determine fully resolved spatial and temporal structure characteristics in a broad class of turbulent flows.

Coupled with this focus on understanding basic physical mechanisms is the goal of controlling these flows by passive, active, and interactive techniques. Research on turbulence control will target the development of new strategies for mixing enhancement and drag reduction. A central issue is the application of formal control theory to guide the development of feedback control methodologies. Other issues center on state estimation and the limitations imposed by sparse arrays of sensors and actuators.

Current research also addresses new theoretical frameworks for the description of turbulent flows. These include chaos and dynamical systems theory as well as renormalization group approaches for the development of subgrid turbulence models. Progress on both the theoretical and experimental efforts, together with a planned initiative in FY 90 on direct numerical simulation of turbulence, will support the future development of a new generation of predictive turbulence models. Numerical simulation will allow the direct testing of ideas and assumptions underlying various approaches to turbulence modelling and provide direct information on the structure and dynamics of turbulence.

Objectives and Applications: The goal of this research effort is to develop an understanding of the fundamental mechanisms governing the onset and evolution of turbulence in shear flows, and to apply this understanding to develop predictive techniques for turbulent flows and to develop new concepts for controlling their behavior.

Present engineering turbulence models are based on statistical formulations that cannot capture important physical mechanisms, such as counter-gradient diffusion, and they do not preserve phase relations associated with deterministic coherent motions which occur at various scales in various generic turbulent flows. These models require empirical calibration and perform poorly in complex flows. Turbulence modeling is a key pacing item for the development of predictive, computational fluid dynamics, a major thrust in the External Aerodynamics Research Effort. Improved turbulence prediction hinges on the ability to incorporate into new turbulence models realistic representations of coherent, deterministic motions in turbulent

flows, together with accurate models of fine-scale turbulence in the wall region of boundary layer flows. Experimental techniques, together with direct numerical solutions to the full Navier Stokes Equations, offer promise for developing truly predictive turbulence models.

Approaches to turbulence control have generally been limited to passive techniques consisting of boundary modifications. With the advent of solid state devices and computers, active control using feedback techniques offers new avenues for the control of boundary layers and free shear layers.

More powerful predictive techniques will lead to the development of improved heat transfer in turbine engines and contribute directly to the Integrated High Performance Turbine Engine Technology Program. They will also provide new capabilities for the prediction of laser beam degradations due to propagation through turbulent shear layers and stimulate the development of control techniques to minimize these aberrations. New turbulence control strategies will lead to active control and enhancement of mixing in high speed combustor applications, and to the development of new drag reduction concepts for flight vehicle applications.

Relationship to Other Programs: In collaboration with the Office of Naval Research (ONR), this research effort supports a current evaluation of the international data base on the structure of turbulent boundary layers. The overall program is coordinated with ONR and the Viscous Flow Branch at NASA Langley through informal interactions. In addition, a proposed FY 90 Research Initiative in Turbulence Simulation will be coordinated with the Center for Turbulence Research at NASA Ames.

Initiatives: The FY 89 Research Initiative in Interactive Flow Control, described in more detail in Part IV, seeks to explore the interdisciplinary frontier between fluid mechanics and control theory to develop new concepts for feedback control of turbulent flows.

UNSTEADY AND SEPARATED FLOWS

The research effort will study the nature of unsteady boundary layers near the location of evolving, time-dependent flow separation. The influence of motion time history on evolution and control of vorticity dominated flowfields will be examined both experimentally and computationally. In addition, mechanisms for unsteady lift generation on wings by means of energetic separation will be examined for a wide range of motion and flow conditions. Of particular interest are the effects of motion history, three-dimensionality, compressibility, and Reynolds number. Analytical and numerical methods will be sought that can capture the key features of unsteady, separated flow and thus be used with confidence for flow prediction.

The basic equations governing flight mechanics will be reformulated to provide a system of equations that encompass the full nonlinearity and time dependence of dynamically maneuvering aircraft. The unsteady flow physics elucidated from the first portion of this research effort will be coupled with the full nonlinear flight mechanics equations to provide realistic

prediction and design models for advanced high maneuverability fighters. Finally, real-time flow control techniques for unsteady vorticity dominated flow fields will be investigated for enhancement and exploitation of the unsteady flow fields elicited by rapidly maneuvering aircraft.

Objectives and Applications: The major objective of this research is to develop an understanding of the dynamics of separating unsteady flow resulting from imposed time-dependent boundary or initial conditions. The goal is to identify, characterize, predict and control unsteady flow phenomena which may be exploited for enhanced aerodynamic maneuverability. Incorporation of prediction and control capabilities for unsteady separated flows with new approaches to nonlinear flight mechanics is a major challenge.

This research will provide basic data and predictive design and evaluation tools for the X-31 Demonstrator Program as well as the development of stores separation technology for advanced weapon systems.

Relationship to Other Programs: A joint research program with DARPA will be initiated in FY 89 and will involve the Frank J. Seiler Research Laboratory, the Department of Aeronautics at the US Air Force Academy, and the University of Colorado at Boulder and Colorado Springs. The program is closely coordinated, through the Supermaneuverability Steering Group, with work being conducted by the Air Force laboratories and by the Navy and NASA.

INTERNAL FLOWS

Experiments will be conducted to isolate key physical mechanisms affecting heat transfer rates in gas turbine engines. These include the effects of wall curvature, end wall secondary flows, free stream turbulence, and wake interactions with following blades. The mass transfer analogy will be used in experiments to simulate active turbine blade cooling effects. Improved efficiency of a transonic rotor will be explored by introducing shock sweep in an experimental demonstration of the concept. The question of efficiency losses associated with flow field unsteadiness and discrete frequency disturbances will be studied in a combined theoretical, computational, and experimental investigation. Studies will be undertaken to quantify multistage interaction effects, and to understand the nature of sources of unsteadiness and instability in axial flow compressors. This work will explore feedback control techniques to expand the range of stable operation.

Objectives and Applications: The goal of this research is to increase our qualitative and quantitative understanding of the aerothermodynamic processes which occur in the turbomachinery environment, and to develop predictive and control techniques for rotating stall and surge in axial flow turbomachinery. Of special interest is the development of improved understanding and prediction of heat transfer in gas turbines. Improved accuracy and computational efficiency is sought for three-dimensional inviscid flow analyses for axial flow compressors. Finally, new approaches are sought for compressor design which will take into account nonsteady effects associated with multistaging.

Inability to adequately predict heat transfer in the gas turbine environment imposes severe limitations in the development of next generation engines.

Recent progress in the simulation of turbulence in simple flows offers new promise for gaining a deeper understanding of the basic physical mechanisms governing heat transfer in the near surface region of turbine blades. This research effort seeks to exploit these developments to provide a new generation of predictive heat transfer models.

Relationship to Other Programs: This research effort directly supports the development of concepts and analysis tools needed for the Integrated High Performance Turbine Engine Technology Program.

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H. PROJECT 2308, ENERGY CONVERSION

1. PROJECT DESCRIPTION: This project involves the efficient use of energy in Air Force propulsion and weapon systems, including airbreathing engines and chemical and non-chemical rockets. Research is organized into the areas of chemically reacting flow, non-chemical energetics, and diagnostics. Chemically reacting flows involve complex coupling between the rate of energy release through chemical reaction and the fluid processes which transport chemical reactants and products and enthalpy. Among systems to be supported by this research are supersonic combustion ramjets for hypersonic flight vehicles, such as the X-30 National Aero Space Plane (NASP) and solid and liquid propellant rockets. Non-chemical energetic systems include plasma and beamed energy propulsion for efficient orbit raising space missions and efficient ultra-high energy thermionic systems for space-based energy utilization. Thermal management of space-based power and propulsion systems will be addressed. The research in diagnostics supports the first two areas by providing critically needed measurement capability for processes such as spray and solid propellant combustion and plasma propulsion.

2. GENERAL OBJECTIVE: The objective of this research is to achieve efficient, controlled energy release for airbreathing and rocket propulsion systems and power supplies. To meet this objective, requires interdisciplinary approaches, including fluid transport processes, chemistry, and physics. Chemical propulsion systems, both airbreathing and rocket, include turbulent mixing and heat transfer, which delimit system performance. In some of these systems, such as the supersonic combustion ramjet, the rate of chemical energy release is finite with respect to the characteristic rates associated with flow, producing behavior fundamentally different from that predicted by isothermal fluid mechanics. Plasmas relate turbulent fluid transport to the behavior of ionized chemical species. The formulation of new methods of measurement requires an understanding of fluid transport processes, particulate behavior, combustion and the response of matter to external stimulation, especially the electromagnetic radiation produced by lasers. Advances in computational capability and experimental methods provide unparalleled opportunities for attaining first-principles understanding and control of energy release mechanisms.

3. RESEARCH EFFORTS:

CHEMICALLY REACTING FLOWS

Research in chemically reacting flows addresses topics in multiphase turbulent reacting flowfields. This body of research is applicable to airbreathing propulsion systems, including gas turbines, ramjets and scramjets, and to chemical rockets.

Objective and Applications: We seek to understand the rate of energy release and the formation of the products of combustion in energetic systems. This understanding will provide the designer/developer with tools to optimize systems in relation to mission requirements with minimum cost and effort. A major emphasis will be given to the problems of achieving complete fuel-air mixing and chemical reaction with minimum shock-related energy losses under supersonic flow conditions, which represent a major design challenge for the NASP. The use of high energy density fuels, such as boron slurries, is being studied. Finally, research is being conducted to reduce problem areas for energy conversion systems which are currently used. Examples of these problems include the reduction in lifetime and the detectable exhaust signature caused by the formation of soot in gas turbine engines; rocket and ramjet failure brought about by combustion instability; and safety/durability concerns for solid rocket propellants.

Relationship to Other Programs: AFOSR research activities are closely coordinated with the Army Research Office and the Office of Naval Research. Research on supersonic combustion contributes directly to the technology efforts of the NASP Joint Program Office. Solid propellant research programs were coordinated with the Energetic Materials Hazard Initiation Team, including participants from Army, Navy and Air Force laboratories.

Initiatives: An initiative on flow control, proposed in conjunction with the 2307 Fluid Mechanics project, will contribute to enhancing the fuel-air mixing processes for the NASP.

NON-CHEMICAL ENERGETICS

The research in non-chemical energetics seeks to find alternative means of chemical energy release to produce the thrust needed to achieve orbit transfer in space. While substantial increases in efficiency have been achieved under idealized laboratory conditions, major challenges remain to demonstrate applicability to future space mission requirements.

Objectives and Applications: This group of research activities is of primary importance to space-based propulsion and weapon systems. Future requirements for boosting payloads from low earth orbit to geosynchronous orbits will grow dramatically. Non-chemical propulsion systems, including electromagnetic and beamed energy devices, offer a six-fold increase in specific impulse with a corresponding three-fold reduction in the propellant-spacecraft mass ratio when compared to current chemical rockets. While plasmas have been generated under transient laboratory conditions, research remains to sustain high energy density operation without excessive electrode wear. For beamed energy systems, barriers to optical access for the efficient transmission of energy must be removed, and approaches for plasma confinement must be explored further. Finding efficient means for rejection of waste thermal energy in space propulsion systems will be a growing need, closely coupled to the use of non-chemical energetic systems.

Relationship to Other Programs: AFOSR research efforts are closely coordinated with the Strategic Defense Initiative Organization and NASA Lewis Research Center.

DIAGNOSTICS

Recent advances in non-intrusive measurement technology have revolutionized experimentation in the physical sciences and engineering. The primary manifestation of these advances is the laser. By coupling laser-based measurements to computer control and data processing, major breakthroughs have been made in the measurement of highly transient, multidimensional physico-chemical phenomena. These advances are particularly relevant to propulsion technology, where the traditional cut-and-try methods of system design and development have proven to be much too expensive and inefficient to meet future requirements. Another exciting dimension to the research on diagnostics is the high potential for transitioning successful research results rapidly into instrumentation which can significantly enhance propulsion technology.

Objectives and Applications: Improved measurement capability is required for reducing the time and cost of research and development in energy conversion systems; for onboard sensing to support active feedback control of system performance; and for the validation of predictive models of physico-chemical processes relevant to energy conversion. For laboratory experiments, emphasis has been placed on the creation of non-intrusive, time-resolved, multidimensional measurements. These measurements are laser-based. In addition, measurement capability is being developed for multiphase reacting flows, including spray combustion and the burning of solid propellants. The temperature and regression rate of solid surfaces are being addressed by the laser-induced fluorescence (LIF) thermometer and the diffuse point interferometer, respectively. The phase-Doppler measurement of drop size and velocity in sprays has been so successful that it is being utilized in Air Force laboratory investigations of fuel spray combustion. The heterodyne interferometer is a follow-on device to the phase-Doppler anemometer, which will provide improved measurement capability with less required optical access. Diagnostic techniques developed for combustion will be extended to plasmas by the selection of appropriate laser frequencies for sensing, and measurement approaches unique to plasmas will be created. Many energy conversion systems preclude optical access, so that laser-based measurements are not possible. Novel means for achieving measurements equivalent to those described above in optically dense media will be sought.

Relationship to Other Programs: Research on multidimensional quantitative imaging of supersonic flows impacts the NASP program. AFOSR efforts on measurement of droplets and sprays are coordinated with related activities supported by the Army Research Office. The research to study the regression rate of solid surfaces, such as electrodes, will be transitioned to the Strategic Defense Initiative Organization.

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I. PROJECT 2309, TERRESTRIAL SCIENCES

1. PROJECT DESCRIPTION: This project provides basic research in geodesy, gravity, and seismology on problems associated with improving missile accuracy and nuclear test ban treaty monitoring. Research in geodesy is required to determine the exact position of targets with respect to missile launch sites. Research in gravity is required to determine the effect on missile guidance systems along flight paths. Research in seismology is required to determine the effect of earthquakes, nuclear explosions, and other natural or system-generated noise on the degradation of missile guidance systems before launch as well as on other Air Force systems and facilities. In addition, seismological research is required for improved nuclear test ban treaty monitoring.

2. GENERAL OBJECTIVE: The objective of this research is to predict the effects of the geophysical processes operating at and near the Earth's surface on AF systems and facilities.

3. RESEARCH EFFORT:

TERRESTRIAL SCIENCES

Research is concentrated in three major areas: geodesy, gravity and seismology. In geodesy, efforts will focus on defining highly accurate satellite orbits using satellite radio receivers at astronomic observatories. In conjunction with other satellite data, geoid positions can be accurately made by knowing the satellite position accurately. The satellite position data will also help to determine the magnitude of gravity more accurately. In addition, gravity research will focus on the testing of a prototype 6-axis, supercooled accelerometer/gravity gradiometer instrument and experiments designed to test the Newtonian nature of gravity. These later experiments include laboratory research (variations of gravity due to the elemental constituency) and large scale efforts (the measurement of gravity along a 2000 foot tower and in a deep borehole in the ice in Greenland). Seismological research is concentrated in two areas. First, the coupling of energy into the Earth's crust to form seismic waves will be studied in detail. Second, properties of the Earth's crust will be studied by observing the propagation of seismic waves.

Objectives and Applications: Research in the terrestrial sciences focuses on predicting the effects of dynamic processes operating at and near the Earth's surface. For improved guidance and location definition, both the shape of the geoid and the magnitude and direction of the Earth's gravity field must be more accurately determined. The coupling of energy into the Earth's crust and the subsequent propagation of seismic waves is of interest for determination of effects on Air Force systems as well as nuclear test

ban treaty monitoring.

The following are specific applications of this research to Air Force technology programs:

- a. Geodetic studies improve azimuth reference systems and launch target position determinations.
- b. Provide the geodetic information required to reduce the CEP of advanced ballistic missile systems.
- c. Gravity investigations support improvements in targeting of strategic weapon systems and weapon delivery.
- d. Develop techniques required to develop precise inertial navigation systems.
- e. Studies in earth motions predict effects of earthquakes, explosions, tides and tilt on stability and vulnerability of missile systems.
- f. Provide the technology to improve the stability of missile guidance systems.
- g. Geodetical and seismological studies apply to advanced missile concepts and predictions of effects of environmental noise on Air Force systems.
- h. Develop more sensitive discriminants between earthquakes and explosive seismic sources.
- i. Develop more accurate yield determination for nuclear test ban treaty monitoring.

Relationship to Other Programs: The DARPA and the National Science Foundation sponsor complimentary research in terrestrial sciences. Seismic research is coordinated between the Air Force and DARPA in an annual research symposium. The 1988 symposium will be the tenth.

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J. PROJECT 2310, ATMOSPHERIC SCIENCES

1. PROJECT DESCRIPTION: Research in the atmospheric sciences includes the physics, dynamics, and chemistry of processes which determine the structure and variability of the earth's atmosphere. Atmospheric properties such as wind, density, clouds and precipitation, ionization, and optical/infrared transmissivity/emissivity all affect the performance of Air Force systems. A major effort is devoted to the development and use of new measurement techniques and the development of models for specifying and predicting weather and other atmospheric conditions. Emphasis is also placed on understanding atmospheric effects on optical and infrared weapons systems and on understanding the dynamics and structure of the ionosphere which affect communications and surveillance systems. Major research efforts focus on the optical/IR environment, ionospheric dynamics, and meteorology.

2. GENERAL OBJECTIVE: The primary objectives of this research are to improve capabilities for specifying and predicting the atmospheric environment with emphasis on those phenomena which have significant impact on Air Force systems. Research will concentrate on developing a more complete understanding of fundamental atmospheric processes to better observation capabilities for specifying important atmospheric parameters; to improve data assimilation techniques to make optimum use of the observed data; and to develop more powerful models to make accurate analyses and forecasts of changes in the environment. These technologies feed applied research programs at the Air Force Geophysics Laboratory (AFGL) for eventual operational transition to the Air Weather Service (AWS).

3. RESEARCH EFFORTS:

OPTICAL/IR ENVIRONMENT

This research specifically focuses on the areas of optical/infrared spectroscopic and sensor techniques/concepts, spectroscopic studies, atmospheric absorption and scattering, theoretical studies of basic molecular interactions, atmospheric transmission modeling, nonequilibrium radiative phenomena, background radiance, and atmospheric effects/interactions associated with lasers, targets, and plumes. Remote sensing of atmospheric and meteorological parameters by optical, infrared, and millimeter wave techniques also make up part of this effort.

Objectives and Applications: The atmosphere can severely impact optical and infrared systems used in communications, surveillance, navigation, and detection. This research effort will involve a wide range of basic investigations leading to the optimization of the design and performance of military systems operating in both quiet and perturbed atmospheric environments through a better understanding of the transmission medium

and/or improved specification of this environment. The basic understanding of the fundamental processes are essential to advance the state-of-the-art in atmospheric transmission models, which are widely used by designers and operators of electro optical systems.

Relationship to Other Programs: The remote sensing aspects of this effort complement the other research efforts outlined below. New optical and IR measurements of the stratosphere, mesosphere, and thermosphere have led to improved understanding of the neutral processes that play an important role in ionospheric dynamics. The Middle Atmosphere Periodic Structure Associated Radiance (MAPSTAR) effort at AFGL is an important component of the Coupling, Energetics and Dynamics of Atmospheric Regions (CEDAR) aeronomy program that is part of the NSF's Global Geosciences Initiative. Improvements in measurements of winds, temperatures, and densities also improve meteorological specification and prediction capabilities. This basic research program is essential to the applied research programs at AFGL which help shape future operational AWS support packages for providing guidance for electro optical weapon and surveillance systems.

Initiatives: An initiative will begin in FY 89 to conceive/refine spaceborne remote sensing capabilities to specify atmospheric density, temperature, and wind structure in the thermosphere. This research will be performed by AFGL and extramural scientists and focus on the contributions of monatomic oxygen in this region. Theoretical and experimental issues will be studied to determine the feasibility of various interferometric remote sensing approaches.

IONOSPHERIC DYNAMICS

This research effort is aimed at defining the physical and chemical properties/interactions of the earth's upper atmosphere and ionosphere and to determine the effects of these properties on Air Force systems operating in or through these regions. The specific subcategories of research involved in this effort are ionospheric physics, ionospheric disturbances, atmospheric chemistry, ultraviolet radiations, and plasma defense technology.

Objectives and Applications: Ionospheric irregularities can seriously degrade the capabilities of the Over-The-Horizon Backscatter (OTH-B) radar to accurately detect and locate airborne targets--the ionosphere is an integral part of the system. Ionization patches in the upper atmosphere can also cause scintillation and loss of communications transmissions from satellite to ground stations and vice versa. Geomagnetic storms can cause electronic problems aboard spacecraft. These are just a few of the impacts that the ionospheric environment can have upon Air Force systems. The objective of this research effort is to develop the fundamental knowledge concerning the atmospheric processes and interactions in these regions needed to improve ionospheric specification and prediction models. These models are used by the AWS to provide operational support to both ground and space-based surveillance and radar tracking, satellite and high frequency communications, satellite anomaly analyses, and manned space flight operations in order to reduce or mitigate degradation problems caused by the ionosphere.

Relationship to Other Programs: This effort benefits from the neutral atmospheric remote sensing and meteorology efforts. It also supports applied research at AFGL and near-earth space forecasting efforts of the AWS. The University Research Initiative efforts at the Massachusetts Institute of Technology and at Utah State University are extremely synergistic with this research effort. There is also a great deal of collaboration among researchers at NASA, the National Oceanic and Atmospheric Agency (NOAA), the Naval Research Laboratory (NRL), the university community and the Air Force, which is often the lead agency on many experimental programs.

Initiatives: Beginning in FY 89, a previous atmospheric chemistry task from Project 2303 will be combined with an existing atmospheric science work effort on upper atmosphere composition to place more emphasis on the chemistry and physics of weakly ionized plasmas. This research will focus on reaction rate measurements, quantum mechanical calculations, and ionospheric theory and experiments.

METEOROLOGY

This research effort is aimed at the underlying physical processes of the atmosphere needed for specifying and predicting weather phenomena. Air Force emphasis is on those phenomena that pose the most significant obstacles to Air Force systems. Subcategories that make up this overall research effort include large-scale dynamics/prediction, intermediate to small scale dynamic/prediction, cloud microphysics, precipitation systems, atmospheric electricity, boundary layer dynamics, climatological modeling, satellite meteorology, and neutral density and dynamics of the troposphere and stratosphere.

Objectives and Applications: Atmospheric effects on Air Force missions are of extreme importance for systems design and mix considerations including deployment, launch, refueling, target detection, acquisition and destruction, communications, and recovery. Weather factors, such as clouds, precipitation, lightning, winds, temperature, humidity, density, and winds, pose threats and/or opportunities to those missions. Improved specification and prediction of these phenomena serve as a force multiplier by aiding in the effective employment of available military resources.

Relationships to Other Programs: Improved atmospheric specifications and predictions serve as inputs needed for accurate atmospheric transmission modeling in the optical/IR environment research effort outlined above. Small scale gravity wave features, which often originate in the troposphere and propagate vertically into the upper atmosphere, also have impacts on ionospheric dynamics as well as meteorology. This research effort also serves to provide the fundamental knowledge needed to spawn applied research and technology transition activities in response to AWS operational requirements.

Initiatives: Modest support to the National Stormscale Operational and Research Meteorology (STORM) program office will begin in FY 89 to help shape this important mesoscale meteorology program. This program will provide researchers with the most sophisticated data and tools for studying

processes that usually are too small to be understood using data from the current operational observing system. Clear air wind profiling radars and doppler radars will be fielded over the next few years and will provide outstanding new observing capabilities. Intensive field campaigns will also be part of the STORM program and provide additional information for more detailed studies. Data assimilation and fine resolution modeling are important thrusts for this program.

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K. PROJECT 2311, ASTRONOMY AND ASTROPHYSICS

1. PROJECT DESCRIPTION: This project provides basic knowledge of the space environment for the design and calibration of advanced Air Force systems. The project also supports the Air Weather Service by improving observing and forecasting techniques that support operational military systems. Space environmental conditions produced by radiation and charged atomic particles can endanger the mission and degrade the performance of military spacecraft, disrupt the detection and tracking of missiles and satellites, distort communications, and interfere with surveillance operations. Experimental and theoretical means are used to study methods to improve space surveillance systems and to study solar outbursts and their travel to the Earth where they affect communications and satellite systems. Also being studied are the composition of the space environment in which Air Force systems operate, changes caused by natural and man-made disturbances, and the response of spacecraft systems and operations to the space environment. The research in this project may be considered under the two subcategories: Solar-Terrestrial Physics and Celestial Backgrounds.

2. GENERAL OBJECTIVE: The objective of this research is twofold: (1) to understand the environmental conditions that significantly affect the survivability and reliability of spacecraft systems as well as propagation conditions for C³I systems; and (2) to define spectral, spatial, and temporal signatures of the celestial background to permit development of effective discrimination techniques.

3. RESEARCH EFFORTS:

SOLAR-TERRESTRIAL PHYSICS

The research addresses some of the most important unsolved problems in solar-terrestrial science. The rapidly expanding role of space in Air Force and DOD operations and missions require significant advances in understanding of the space environment, the development of a new generation of state-of-the-art sensors, a significant expansion of the space parameter data base and new computer simulation capabilities. Research is carried out on the components of the system, that is the sun, interplanetary medium, the magnetosphere and on the connections between them. R&D is carried out in space, in the laboratory, and through analytical, theoretical and computer codes. Active space experiments represent an important new approach to the study of the space environment. Major activities include the development of instruments for solar activity measurements and satellite payload measurements, including solar magnetic fields and extreme ultraviolet with a goal of developing precursors for major solar eruptions that degrade or destroy Air Force satellite systems or which can produce false targets. Solar flare energy buildup and magnetic field gradients will be studied with

the goal of generating new empirical flare forecasting codes. The Sacramento Peak Observatory vacuum tower telescope will be reconfigured to incorporate real-time adaptive optics.

This represents a new era in solar R&D observations. Acceleration mechanisms responsible for the transport of solar particles into the interplanetary medium will be investigated and efforts will be made to predict changes in the direction of the interplanetary magnetic field. These efforts are critical to the development of prediction tools for Air Force and DOD space weather forecasters. Major alterations in the geomagnetic field during large magnetic storms increase the access of very energetic particles and cosmic rays in the polar regions. The study of these processes will provide new capability for specifying the effects of large, intense particle events on Air Force and DOD microelectronics sensors. Dynamic global magnetospheric models will be developed and subsequently parameterized for transition to Air Force space weather forecasters. New sensors have been developed for the AF/DOD space weather satellites which will expand the ability to predict space environments which cause spacecraft sensors malfunction or degradation. Theoretical studies and computer simulations of electron beam propagation and resulting wave generation, heating and optical signatures will be conducted.

A significant increase in the support of solar physics is planned for in FY 90. The specific area to be studied is the physics of recurrent solar activity. A theoretical and observational effort is expected to lead to a verifiable physical model of the eleven year sunspot cycle and the twenty-two year solar magnetic cycle.

Objectives and Applications: The objective of this research is to understand the environmental conditions that significantly affect the survivability and reliability of spacecraft systems as well as propagation conditions for C³I systems. To meet this objective, research is required on solar-magnetospheric-ionospheric interactions, measurements and theoretical studies concerning the Van Allen radiation belts to assess the impact of trapped particles and cosmic radiation on microelectronic systems reliability and lifetime, and the effects of the interplanetary magnetic fields, solar winds and the magnetosphere. Greatly improved understanding of all these processes is needed if one intends to determine environmental parameters important to the survivability of sophisticated, long-lived satellite systems and large, high powered structures in space and to support the design and operation of C³I and surveillance systems.

The following are specific applications of this research to Air Force technology programs:

- a. Predict the occurrence and intensity of enhanced particle fluxes which affect Air Force systems operating in near-Earth space.
- b. Define solar and interplanetary phenomena which can affect the environment in which present and projected USAF systems operate.
- c. Predict the effect of plasma irregularities and motions on Air Force systems and communication.

d. Develop new instruments to measure the wake and sheath properties of spacecraft to study communications, detection and tracking.

e. Forecast solar electromagnetic and particle emissions that disrupt high frequency communications, radars and satellite sensors.

f. Improve satellite imaging techniques to determine the purpose and performance of Earth-orbiting satellites.

g. Determine long term solar energy output variations as input to upper atmosphere models and long-range weather prediction.

h. Determine the spatial-temporal variations of the solar wind at the Earth which produce disturbances that adversely affect Air Force systems.

i. Improve Air Force space vehicle reliability and survivability.

j. Provide data essential for the design and high performance of communication, guidance and surveillance systems under normal and disturbed conditions.

k. Develop techniques of solar observations to be used on Space Shuttle missions.

l. Derive from direct measurements, the characteristics of space shuttle environmental electromagnetic interference (EMI).

m. Provide algorithms for the real-time prediction of solar particle events which disrupt the performance of AF C³I systems.

n. Extend the warning time and impact accuracy of solar particle events using characteristics of solar radio emission.

o. Develop algorithms which can be used as input to satellite radiation dosage calculations for the cosmic ray angle of arrival as a function of energy and momentum.

p. Provide forecasts of dangerous radiation hazard for man-in-space.

q. Improve forecasts of communications disruptions in polar regions.

r. Reduce false alarms from early-warning systems.

s. Improve understanding of particle beam transmission characteristics in space for defense and weapon systems.

Relationship to Other Programs: The Office of Naval Research, the National Science Foundation and the National Aeronautics and Space Administration are conducting and sponsoring complementary research in solar-terrestrial science. Coordination is accomplished during reviews for the Office of the Under Secretary of Defense for Acquisition, Research and Advanced Technology, OUSDA(RAT), at the Science and Technology Review of Environmental Sciences, through formal and informal discussions among

government scientists on programs of mutual interest, and through attendance at symposia and scientific meetings. Cooperative programs include Air Force and National Aeronautics and Space Administration particle and field sensors flown on Air Force satellites and the Space Shuttle and quarterly Space Forecasting Workshops to support the Air Weather Service. Noteworthy collaborative efforts concerning solar-terrestrial predictions and data compilation involve the National Oceanic and Atmospheric Administration. As part of the University Research Initiative, a program designed to improve the quality of research performed at the universities to meet defense needs, a Center for Applied Solar Physics is being established at Johns Hopkins University Applied Physics Laboratory. This center will improve solar activity observations and prediction techniques by instrumentation development and solar magnetic field research. The design and fabrication of a vector magnetograph will be the keystone of the program. The instrument will be based on ultra-narrow passband tunable filter technology.

CELESTIAL BACKGROUND

The initiation of a laboratory task to gather and analyze infrared stellar and celestial background data and to improve ground-based instrumentation indicates the importance of stellar and celestial sources to the problem of infrared surveillance activities. Methods of detecting space objects against the celestial infrared background will be developed. Sources of infrared radiation will be observed and classified. Models will be formulated to permit the derivation of discrimination techniques. Detailed knowledge of the infrared background sky brightness will be obtained. Accurate measurements will be made of the position and irradiance of celestial infrared sources. Information will be provided on the optical and physical properties of celestial infrared sources, including their location, origin, dynamics and contribution to the infrared astronomical background. The celestial research on infrared signatures will be advanced through a data collection program from a mosaic array spectrometer. Speckle image reconstruction techniques will be evaluated, developed and applied using astronomical data from large ground-based telescopes. The infrared studies will seek to determine spectral contamination of the 8 to 14 micron band by background spectral structures as a function of the viewing geometry.

Objectives and Applications: This research seeks to define spectral, spatial and temporal signatures of the celestial background to permit development of effective discrimination techniques. This work will lead to the establishment of bandpasses for surveillance sensors optimized to filter emissions structures which degrade the capability of infrared surveillance sensors.

Relationship to Other Programs: The Naval Research Laboratory, the National Science Foundation and the National Aeronautics and Space Administration are conducting and sponsoring complementary research on the celestial background. A collaborative effort with the scientists involved in the European Space Agency Infrared Satellite Observatory will collect new high resolution angular and spectral infrared celestial data needed to interpret and define the operation of Air Force surveillance sensors.

Initiative: In FY 89, an initiative at the Air Force Geophysics Laboratory

will permit collaboration on the IR Satellite Observatory and the support of high spatial resolution Infrared Astronomy. The scientific goal for the initiative is the determination of the infrared emission mechanisms for regions of star formation, celestial objects embedded in dust, star-burst galaxies and the fine scale structure of molecular clouds, interstellar dust, zodiacal dust and asteroids. This work has application to space based space surveillance, space based ASAT, USAF manned space station and the space based reusable orbiter.

AFOSR Focal Point: Dr Key Dismukes
Telephone: (202) 767-4278

L. PROJECT 2312, BIOLOGICAL AND MEDICAL SCIENCES

1. PROJECT DESCRIPTION: This project consists of three research efforts: (1) chemical toxicology and biological effects of radiation, (2) neuroscience and (3) physiology and biophysics.
2. GENERAL OBJECTIVE: To provide knowledge needed to protect Air Force personnel and to enable them to perform effectively in hostile environments.
3. RESEARCH EFFORTS:

CHEMICAL TOXICOLOGY AND BIOLOGICAL EFFECTS OF RADIATION

Research on chemical toxicology examines how chemicals exert toxic effects and how the body responds, cellular and molecular markers for exposure, pharmacokinetic modeling of toxicity, and extrapolation of dose effects from laboratory animals to humans. In FY 88 USAF/LEEV contributed \$800K to expand research on the environmental fate and impact of chemicals released in Air Force operations. In FY 89 AFESC will begin a task developing bacteria that can degrade chemicals spilled into the ground. We are also examining the biophysical mechanisms by which radiation damages living cells and are seeking compounds that will protect individuals from radiation damage.

Objectives and Applications: Jet fuels, lubricants, solvents, herbicides, propellants, explosives, and other exotic aerospace materials used in Air Force operations all contain toxic chemicals. Even stringent handling precautions cannot always prevent exposure of personnel to these toxic chemicals, especially in wartime conditions. Additionally, Air Force personnel could be exposed to ionizing radiation in either space operations or nuclear warfare.

Relationship to Other Programs: The Environmental Protection Agency and the National Institute of Environmental Health Sciences have extramural and intramural research programs in this domain. However, neither agency emphasizes basic research on chemicals of the sort used in Air Force operations.

Initiatives: A FY 89 initiative will provide funds for several new Air Force laboratory research tasks in life sciences. One of these new starts will be the AFESC study of microbial degradation of toxic chemicals.

NEUROSCIENCE

We are studying the neurobiological mechanisms underlying arousal, vigilance, stress, fatigue, biological rhythms, learning and memory, and

other cognitive functions. In collaboration with projects in electronics and mathematics, we also support multidisciplinary studies of neural networks, computational models of information processing, especially those with features that allow learning.

Objectives and Applications: Air Force personnel must perform with skill and precision in highly stressful situations. Frequently they must move across time zones or work on schedules that disrupt normal sleep/wake patterns. By discovering the neurobiological mechanisms involved, we will be able to reduce or prevent the negative effects of these situations on task performance. Studies of neural networks will provide new approaches to computer architectures that can learn from experience, recognize patterns, and show resilience to component failures. This will greatly advance development of smart weapon systems.

Relationship to Other Programs: The National Institutes of Health has a large neuroscience program; however, it focuses on the neurobiology of disease. The National Science Foundation and the Office of Naval Research have neuroscience programs; however, they do not focus on the same topics as our program.

PHYSIOLOGY AND BIOPHYSICS

One task under this effort examines the effects of vibration and loading on the skeletal system, especially the growth of new bone tissue. Another task uses extremely short (femtosecond) laser pulses to study the basic molecular events underlying detection of light by the eye. Supported by initiative funds, a new task will begin in FY 89 to study subclinical cardiovascular diseases in aircrew. Another new task will examine the effects of acceleration on cerebral blood flow.

Objectives and Applications: Aircrew are subjected to prolonged vibration throughout their flying careers. Studying the effects of vibration on formation of bone tissue will help us find ways to prevent pathological effects. Research on the mechanism of light detection will help improve night vision devices. Subclinical (no overt pathology observed) cardiovascular irregularities are a major cause for removing aircrew from flight status. This research will help us determine whether it is always necessary to remove aircrew with only subclinical irregularities. Research on cerebral blood flow will help us find ways to prevent G-induced loss of consciousness in high-performance aircraft.

Relationship to Other Programs: The National Institute of Health supports research on the molecular mechanisms of phototransduction. We are not aware of substantial programs in subclinical cardiovascular disease, G-induced loss of consciousness, or effects of vibration on bone growth.

Initiatives: A FY 89 initiative will provide funds for USAF School of Aerospace Medical Research Laboratory (USAFSAM) for the new tasks on subclinical cardiovascular disease and the new task on G-induced loss of consciousness.

AFOSR Focal Point: Dr Key Dismukes
Telephone (202) 767-4278

M. PROJECT 2313, HUMAN RESOURCES

1. PROJECT DESCRIPTION: This project supports research on human information processing. The research efforts are (1) vision, (2) audition, and (3) cognition.

2. GENERAL OBJECTIVE: The objective of this research is to provide knowledge of human information processing so that equipment can be designed appropriately, the right people can be selected for the right jobs, and those people can be trained effectively for those jobs. Modern sophisticated, expensive equipment systems are useful only to the extent that they can be operated effectively by humans. For example, the number of displays and controls in military aircraft, the flood of information presented to the pilot, and the rate at which things happen, place severe demands on the human ability to select and digest information quickly and respond appropriately.

3. RESEARCH EFFORTS:

VISION

This research examines how humans extract information from the world around them, analyze that information, recognize patterns, and use the information to guide their actions. For example, how do we recognize objects and distinguish objects from background? How do we determine motion and distinguish self-motion from object motion? We perform these tasks so effortlessly in everyday life that it is easy to overlook the enormous complexity of the computations involved. Attempts to make machines capable of recognizing real-world scenes have so far met with limited success.

Objectives and Applications: This research will provide knowledge for setting appropriate vision standards for aircrew, improving design and use of flight simulators, and improving design of visual displays in cockpits and other equipment consoles. It will also stimulate new approaches to designing machines capable of recognizing visual scenes from the real world.

Relationship to Other Programs: The National Institutes of Health has a large program of vision research; however, it does not focus on the theme of our program.

Initiatives: A FY 89 initiative in sensory neurophysiology will support research at the intersection of vision neurophysiology and vision psychophysics.

AUDITION

This research examines how humans recognize complex sounds, including but not limited to speech. How is the source of a sound located? What features are extracted from complex sound patterns? How are these features analyzed and combined so that a sound pattern is recognized? What are the roles of learning and memory in recognizing speech and other complex sounds?

Objectives and Applications: This research should lead to techniques for increasing the intelligibility of spoken messages and warning signals in noisy and stressful environments. It will also provide ways to reduce the mental workload of human operators flooded with incoming information. We also expect this research to open up new approaches to designing machines capable of sophisticated recognition of speech.

Relationship to Other Programs: The National Institutes of Health has a large program in audition; however, it focuses on pathology. The National Science Foundation and the Office of Naval Research have auditory programs but with different emphasis than ours.

Initiative: A FY 89 initiative in sensory neurophysiology will support research at the intersection of auditory neurophysiology and auditory psychophysics.

COGNITION

This research examines the mechanisms of perception, attention, working memory, organization of knowledge, learning, reasoning, judgment, and problem-solving. How do experts at real-world skills, such as flying aircraft, differ from novices in these mental functions? To what extent does expertise on one task generalize to broader areas? Can we predict individual abilities to perform real-world tasks by measuring these mental functions? An Air Force Human Resources Laboratory (AFHRL) task has developed a major computer facility to study the mental abilities of large numbers of subjects and is now testing all new Air Force recruits. AFHRL scientists are collaborating with university scientists to analyze the enormous amount of data generated by this task.

Objectives and Applications: This research will improve our ability to select individuals for military jobs on the basis of their abilities, and it will improve our ability to train individuals to perform those jobs well. We will also be able to design jobs and equipment systems to avoid excessive mental workload and minimize human errors. In addition this research will stimulate more sophisticated approaches to artificial intelligence.

Relationship to Other Programs: Several agencies have small programs in cognition, though none with quite the same focus as ours.

IV. RESEARCH INITIATIVES FOR FY 1989.

This section describes the new research efforts which are planned for FY 1989.

RESEARCH INITIATIVE

TITLE: Wafer Scale Union - Optics

FOCAL POINT: Dr. Howard Schlossberg, AFOSR/NP, (202) 767-4906

REFERENCE: Project 2301 Task A1

<u>FUNDING:</u>	<u>FY 89</u>	<u>FY 90</u>	<u>FY 91</u>	<u>Total</u>
	\$450K	\$450K	\$450K	Continuing

OBJECTIVE: The objective of this research is to study materials, techniques, device concepts, and integration schemes to advance the state-of-the-art in wafer scale union. The use of optical techniques will be particularly emphasized.

TECHNICAL DESCRIPTION: Wafer scale union refers to the technological possibilities of integrating microwave, optical, electronic, mechanical, and sensor elements on single wafers to perform complex system functions compactly and inexpensively. Optical techniques, particularly in integrated form, hold great promise for achieving the goals of wafer scale union.

APPROACH: Optical techniques will be studied for on-chip distribution of signals to mechanical and electronic (digital and high frequency analog) devices. The use of integrated optical waveguides to distribute phase in order to phase lock independent devices will be studied, both for power enhancement as well as for controlling antenna patterns. Three dimensional processing and integration techniques will be emphasized in order that radiating elements, or elements that must see the environment, such as sensors, can be effectively isolated from radiation or environmentally sensitive elements. The research will focus on study and demonstration of the integration of control, sensing, and signal processing techniques which are potentially scalable to high levels.

RESEARCH INITIATIVE

TITLE: Half-Collisions

FOCAL POINT: Ralph Kelley, AFOSR/NP, (202) 767-4908

REFERENCE: Project 2301 Task A4

<u>FUNDING:</u>	<u>FY 89</u>	<u>FY 90</u>	<u>FY 91</u>	<u>TOTAL</u>
	\$250K	\$250K	\$250K	Continuing

OBJECTIVE: This program will contribute to the analysis of combustion processes, atmospheric chemistry, rocket plumes, and nuclear weapons effects -- all areas of technology that can benefit from a deeper understanding of collisional reaction processes. Technological applications in these areas depend on modelling of the processes, usually by computer codes. These models are only as good as the description of the basic collisional process that is used in the computer codes.

TECHNICAL DESCRIPTION: Lasers can now be used to break apart polyatomic molecules by irradiation with ultraviolet light or even through multiphoton absorption of infrared light. As the molecular fragments then fly apart they trace a trajectory which is similar to that traced by particles in a collision, except that only the second half of the collision process occurs. Study of this type of process has certain advantages not present when ordinary collision processes are studied. In a normal collision process, the initial states of the colliding particles can be carefully prepared, i.e., the entrance channels of the reaction are well-defined, but there are many different intermediate (or transition) states, as well as many possible exit channels. Thus the analysis of the results of a collision experiment is not clear cut. If lasers are used to place polyatomic molecules into well-defined states which can then dissociate, the intermediate or transition state is now well-defined and the analysis becomes much simpler.

APPROACH: Laser excitation will be used to put molecules into well-defined states which will dissociate into fragments. The molecular fragments will then separate, following trajectories similar to those of the second half of a collision between the fragments. Both experimental and theoretical studies of these processes will be conducted.

RESEARCH INITIATIVE

TITLE: Mesomechanics

FOCAL POINT: Lt Col George K. Haritos, AFOSR/NA, (202)767-0463

REFERENCE: Project 2302 Task B2

<u>FUNDING:</u>	<u>FY 89</u>	<u>FY 90</u>	<u>FY 91</u>	<u>TOTAL</u>
	\$750K	\$750K	\$750K	Continuing

OBJECTIVE: The objective of this initiative is to establish the correspondence between microstructural features and mechanical behavior to enable design of the microstructure for optimum properties.

TECHNICAL DESCRIPTION: Interdisciplinary research is needed to illuminate the physical processes and mechanisms which will control the response of future structural systems. Interests lie in identifying, mathematically modeling, and experimentally observing the mechanisms governing the behavior of structures subjected to a wide spectrum of mechanical, thermal, chemical, and electromagnetic loading.

APPROACH: The main thrust is in the constitutive modeling of multiphase materials, to include the interactions associated with material microstructure, and the onset and evolution of damage as a time-dependent process. The unprecedented levels of reliability demanded of future aerospace systems will require a fundamental understanding of the response of structural materials to very high temperatures and severe temperature gradients and to high energy bombardment. Research issues include transient dynamic thermo-mechanical modeling, damage development and failure criteria, and associated diagnostic techniques. Of significant interest is also the inelastic response of fixed-base structures subjected to impactive and impulsive excitations, and the associated dynamic effects, including high strain rates in construction materials. Progress in these research areas will require advances in both experimental and computational mechanics through novel applications of state-of-the-art instrumentation and computer hardware and software, including parallel processing and artificial intelligence, respectively.

RESEARCH INITIATIVE

TITLE: Novel Surface Chemistry For Solid Lubrication Of Ceramics

FOCAL POINT: Lt Col Larry W. Burggraf, AFOSR/NC, (202) 767-4960

REFERENCE: Project 2303 Task A2, Q1

<u>FUNDING:</u>	<u>FY 89</u>	<u>FY 90</u>	<u>FY 91</u>	<u>TOTAL</u>
	\$500K	\$500K	\$500K	Continuing

OBJECTIVE: The objective of this initiative is to model and understand interface interactions at lubricated surfaces to provide the scientific basis to create novel solid lubricated ceramic bearing systems which are effective and chemically stable over a wide temperature range. At present no rational, first-principles model exists for prediction of tribological properties of novel materials to guide their development. This surface chemistry research is aimed at understanding and controlling the friction and wear produced by lubricant-substrate interactions, interacting interface topography and tribochemistry by developing atomic-scale mechanisms for these processes.

TECHNICAL DESCRIPTION: Improved solid lubricated systems are essential to future aerospace systems, particularly those with heavily loaded elements operating at high temperatures or precision pointing and tracking requirements in a variable temperature environment. Future Air Force propulsion systems will operate at higher temperatures to achieve marked increases in performance. In particular, engines for the national aerospace plane require tribological elements with properties that do not now exist. Further, greatly extended lifetimes for tribological elements will be required for future space-based cryocoolers and turbopumps. An Institute for Defense Analysis (IDA) study of critical tribological needs for defense systems planned for the future has shown that solid lubrication of ceramics is the pervading technological shortfall.

APPROACH: Understanding the mechanisms of adhesion and wear at interfaces is the key factor to further development of the technology base for tribology. Both experimental and theoretical techniques are now becoming available to attack this important and complex problem in a systematic, scientific manner, giving detailed atomic scale descriptions of interactions at interfaces. This initiative will emphasize creating and evaluating novel nanometer-scale surface structures for self-lubricating composites, wide temperature range solid lubricant materials, and ultra-low wear lubricated surfaces. New tribological surfaces will be created by applying technologies used for electronic materials fabrication, including laser assisted deposition, ion assisted deposition and reactive ion deposition. These deposition techniques enhance structural control in heteroepitaxial layers to produce novel surface structures having unique properties. This research will: (1) computer model static and dynamic interactions at solid

interfaces, (2) develop atomic-scale mechanisms of solid interface interactions in lubricated ceramic systems to model tribological properties, (3) use novel surface modification technology to produce low wear, ultimately smooth ceramic bearing surfaces and solid lubricant films (4) characterize surface structure and surface chemistry of novel oxide, nitride, and carbide ceramic surfaces, including fluorided diamond surfaces as candidate ceramic bearing surfaces, (5) provide fundamental tribology characterization of ultimately smooth, lubricated ceramic and diamond surfaces using force microscopy and tunneling microscopy, and (6) characterize structure and chemistry of ceramic-lubricant interface for model lubricant systems, such as lubricious oxides, fluorocarbon polymers, and model dichalcogenides.

RESEARCH INITIATIVE

TITLE: Sol-Gel Electrooptics

FOCAL POINT: Dr Donald R. Ulrich, AFOSR/NC, (202) 767-4963

REFERENCE: Project 2303 Task A3

<u>FUNDING:</u>	<u>FY 89</u>	<u>FY 90</u>	<u>FY 91</u>	<u>TOTAL</u>
	\$500K	\$500K	\$500K	Continuing

OBJECTIVE: The objective of this initiative is to provide new high-efficiency, second-and third-order nonlinear optical (NLO) nonmetallic materials by controlled ordering and molecular design. Recent advances in AFOSR solution ceramic and NLO polymer research will be applied to formulate unique structures on the ultrastructure level.

TECHNICAL DESCRIPTION: Air Force basic research has developed the high performance ordered polymers, which have shown large nonresonant, broadband third-order nonlinear optical activity; new high second order pendant side chain polymers; and sol gel glasses, which have excellent optical quality and ultrastructure control. For example, the pores can be oriented and tailored at any uniform size from 20 to 500 Angstroms. Preliminary experiments have shown that optical activity can be significantly enhanced when ultrastructures are fabricated from combinations of these materials by impregnation or copolymerization. The ease of processing these ultrastructures into simple or complex shapes with excellent mechanical integrity and environmental stability opens new opportunities for optical computing, optical signal processing, optical storage, and optical sensor protection.

APPROACH: Sol-gel-NLO polymer composites will be synthesized for enhanced second and third nonlinear optical activity. The macroscopic second and third order susceptibilities, $\chi^{(2)}$ and $\chi^{(3)}$, respectively, can be enhanced several orders by a few percent of polymer. In the second order case, this can be higher than the homopolymer; in the third order case, it can be higher than state-of-the-art polymer composite waveguides. A self-induced polarization mechanism has been observed in the second order case. Research will be directed toward understanding these mechanisms and designing multifunctional (both $\chi^{(2)}$ and $\chi^{(3)}$) ultra structures. The recently discovered new third order NLO mechanism in ordered and ladder polymers based on intramolecular charge transfer offers new synthesis options for ordered polymer molecules and cosynthesis with sol-gel molecules.

RESEARCH INITIATIVE

TITLE: Ultraviolet Radiation Mechanisms

FOCAL POINT: Dr. Francis J. Wodarczyk, AFOSR/NC, (202) 767-4963

REFERENCE: Project 2303 Tasks B1, G3, M3

<u>FUNDING:</u>	<u>FY 89</u>	<u>FY 90</u>	<u>FY 91</u>	<u>TOTAL</u>
	\$450K	\$450K	\$450K	Continuing

OBJECTIVE: Most current tracking and surveillance from satellites is accomplished using infrared detectors. Recent advances in detector sensitivity in the ultraviolet have caused us to reassess the relative merits of the two spectral regions. The ultraviolet affords many advantages over the infrared, including potentially better aim-point prediction, smaller aperture for the same resolution, smaller weight, no cryogenic temperatures, enhanced detector sensitivity, reduced background radiation, and resistance to present countermeasures.

TECHNICAL DESCRIPTION: This initiative is aimed at providing a sound fundamental data base for ultraviolet field observations by studying the formation and kinetic processes associated with molecular emissions from missile plumes, airglows, and auroras. Both experimental and theoretical work will be undertaken through a coordinated program involving the AF Geophysics Laboratory, AF Astronautics Laboratory, and extramural contracts. The ultimate goal is the development of models to predict and characterize ultraviolet emissions from missile plumes as well as in the natural and disturbed atmospheres.

APPROACH: A combined analytical and experimental program is anticipated. Experimental studies of the products of combustion reactions which produce ultraviolet emitting species, such as NO, CO, OH, and N₂, will be studied under a variety of different equivalence ratios ranging from fuel rich to oxidizer rich and under a variety of pressures and expansion conditions. Measurements will use various laser- and electron-beam based diagnostic techniques to determine the spectroscopy, kinetics, and internal energy states of the various species of interest. Existing computer-based combustion codes will be used to model the energy exchange process and specific reaction chemistry. Sensitivity analysis will be performed to determine the relative importance of processes involved.

RESEARCH INITIATIVE

TITLE: Parallel Algorithms for Optimization

FOCAL POINT: Dr Charles J. Holland, AFOSR/NM, (202) 767-5025

REFERENCE: Project 2304 TASK: A8

<u>FUNDING:</u>	<u>FY 89</u>	<u>FY 90</u>	<u>FY 92</u>	<u>TOTAL</u>
	\$500K	\$400K	\$300K	Continuing

OBJECTIVE: The objective of this research is to advance the development of optimization algorithms to effectively use the capabilities of a broad class of parallel computers.

TECHNICAL DESCRIPTION: Research is directed toward error analysis and convergence rates of solutions obtained by parallel algorithms; compatibility of machine architecture, parallel algorithms, and the optimization problem; types of algorithms appropriate for a given problem structure (e.g., synchronous, asynchronous, chaotic); problem decomposition; and measures of performance for algorithms on parallel computers. Parallel algorithms for both large-scale linear and nonlinear programming problems are of interest. Applications include large-scale optimization problems such as those associated with allocation and scheduling in complex transportation systems, or structural optimization problems found in the design of aircraft.

APPROACH: Funding will be directed toward approaches that take advantage of the emerging parallel computing power. Goals include reducing computing time required to solve large-scale optimization problems and expanding the size and complexity of problems which can be tackled. Research will be directed at both developing the underlying theory and at deriving fast algorithms to solve optimization problems.

RESEARCH INITIATIVE

TITLE: Inverse Scattering

FOCAL POINT: Dr Arje Nachman, AFOSR/NM, (202) 767-5025

REFERENCE: Project 2304 Task A9

<u>FUNDING:</u>	<u>FY 89</u> \$300K	<u>FY 90</u> \$400K	<u>FY 91</u> \$400K	<u>TOTAL</u> Continuing
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OBJECTIVE: The objective of this initiative is to provide the mathematical formalism, both analytical and computational, necessary to deduce the nature of a scattering object from the backscattered data.

TECHNICAL DESCRIPTION: Inverse scattering theory is concerned with determining the physical properties of an unknown inhomogeneity in a medium based on a knowledge of its effect on a given acoustic, elastic, or electromagnetic wave. It has practical applications to situations where the unknown inhomogeneity is not accessible to direct observation. Some of these applications, such as in radar and sonar, are now classical, although recent developments have progressed to where it will soon be possible to use such methods to distinguish between objects of similar size and shape. More recent applications of inverse scattering theory are concerned with the use of ultrasound to detect tumors in the body, elastic waves to determine the location and shape of flaws in materials, and elastic or electromagnetic waves to determine the location of mineral deposits in the earth. In all these areas, we can determine something with existing methods, but not well enough. The field is ripe for major breakthroughs, some of which are already taking place.

The mathematical problems associated with inverse scattering theory are in general not only highly nonlinear but also improperly posed in the sense that the solution does not depend continuously on the measure data. Since experimental data are always contaminated by noise, a prior knowledge must be used to stabilize the problem. Moreover, when posed as optimization problems, the nonlinearities admit multiple local minima. This means that to obtain the correct solutions, new and innovative optimization strategies must be developed. In addition to being nonlinear and improperly posed, the frequency of the probing wave is of crucial importance and different frequency regimes require different mathematical methods. Inverse problems that are physically realistic are very large computational problems. They are currently being studied through the theory of partial differential equations, numerical methods, optimization schemes, and functional analysis.

The insight gained from the mathematical analysis of various inverse scattering problems, together with the advent of supercomputers, has made it theoretically possible to actually reconstruct in real time three-dimensional inhomogeneities from inexact experimental data. In a

special case, this has in fact already been accomplished for time-harmonic acoustic waves with frequency in the resonance region (i.e., intermediate values of the frequency) and a goal of this initiative is to extend the analysis to more realistic inverse scattering problems for acoustic waves as well as the more complicated case of electromagnetic and elastic waves.

APPROACH: Recent developments in the theories of partial differential equations, numerical methods (particularly using parallel computing), optimization algorithms and functional analysis will be used to investigate the inverse scattering problem. Novel approaches will be sought for both the analysis and computation of realistic inverse scattering problems for acoustic, electromagnetic, and elastic waves.

RESEARCH INITIATIVE

TITLE: Wafer Level Union-Electronics

FOCAL POINT: Gerald Witt, AFOSR/NE, (202) 767-4931

REFERENCE: Project 2305, Task C1

<u>FUNDING:</u>	<u>FY 89</u>	<u>FY 90</u>	<u>FY 91</u>	<u>TOTAL</u>
	\$550K	\$550K	\$550K	Continuing

OBJECTIVE: The objective of this initiative is to develop the capability to monolithically integrate multiple functional elements on a common substrate.

TECHNICAL DESCRIPTION: At present, high density digital electronic requirements (e.g., data storage and processing) are addressed by circuits fabricated on 6-inch silicon (Si) wafers. Analog (radar transmission and detection) and optoelectronic (solid state lasers and detectors) needs are met by discrete devices fabricated from 2-inch and 3-inch compound semiconductor wafers. This initiative seeks to develop the capability to combine on a common substrate, e.g., 6-inch Si wafer, all of the devices and circuits needed for advanced Air Force electronic systems. An example is phased array radar in which transmission, detection, and signal processing are accomplished on one substrate.

APPROACH: The monolithic integration required for these applications calls for the development of several novel technical capabilities. One of these is the ability to grow one type of material on another (heteroepitaxy); for example, the growth of gallium arsenide (GaAs) on Si. These materials differ in crystal type and dimensions, thermal expansion coefficient, and thermal conductivity. These differences complicate the overgrowth process and typically produce inferior GaAs. One of the major goals of this initiative is to develop a general understanding of heteroepitaxy and to apply this knowledge to those processes required by wafer level integration. AFOSR/NE will concentrate on general heteroepitaxy issues using GaAs on Si as a prototype. Rome Air Development Center will explore heteroepitaxy on high resistivity substrates, a special requirement of high frequency applications. These efforts will be coordinated with complementary activities in AFOSR/NP dealing with optoelectronic applications.

RESEARCH INITIATIVE

TITLE: Computational Materials Science

FOCAL POINT: Alan Rosenstein, AFOSR/NE, (202) 767-4933

REFERENCE: Project 2306, Task A1

<u>FUNDING:</u>	<u>FY 89</u>	<u>FY 90</u>	<u>FY 91</u>	<u>TOTAL</u>
	\$400K	\$400K	\$400K	Continuing

OBJECTIVE: This initiative has the following objectives: to establish the fundamental basis of methodology to provide comprehensive and systematic improvement of existing materials and development of new materials; to understand and explain mechanical properties of materials and their fundamental relationship to microstructural and compositional variations; and to undertake a fundamental exploration of the full potential of computational methods to obtain improved engine, airframe and spacecraft structural materials, and design and synthesis of new, advanced material systems for these applications.

TECHNICAL DESCRIPTION: This effort will involve interdisciplinary research in materials science, physics, processing science, and computer science. The research is driven by recent advances in the theoretical, computational, and experimental tools available to materials scientists. The program is a joint effort, equally shared by AFOSR/NE and AFWAL/MLLM. AFOSR efforts will focus on ab initio calculations, modeling and simulations of microstructure, controlled experimental verification, and approaches to synthesis of new material systems. AFWAL/MLLM efforts will focus on an alternative to experimentally determine the property and alloying behavior of materials, i.e., to apply the advanced methods of computational physics to model their behavior and to compute their properties.

APPROACH: The approach is to evaluate the state-of-the-art in computational modeling methods as applied to solid metallic systems; to develop theoretical methods which are suitable for modeling the physical properties, mechanical behavior and alloying behavior of intermetallic systems; and to verify these theoretical methods on selected intermetallic systems. This approach promises to be particularly fruitful since one of the difficulties in exploring the potential of intermetallic materials (and structural materials in general) is an insufficient data base to assess the physical properties, mechanical behavior and alloying behavior, of these materials.

RESEARCH INITIATIVE

TITLE: Interactive Flow Control

FOCAL POINT: James M. McMichael, AFOSR/NA, (202) 767-4936

ROADMAP REFERENCE: Project 2307, Task A2

<u>FUNDING:</u>	<u>FY 89</u>	<u>FY 90</u>	<u>FY 91</u>	<u>TOTAL</u>
	\$1,000K	\$1,000K	\$1,000K	Continuing

OBJECTIVE: The objective of this initiative is to provide new concepts for interactive flow control technologies.

TECHNICAL DESCRIPTION: This initiative seeks to explore the interdisciplinary frontier between fluid mechanics, combustion sciences and control theory to develop new concepts for feedback control of turbulent and reacting flows. There is a critical need for new flow control strategies which can be tailored to specific applications requiring enhancement of suppression of instabilities and turbulence. Research will target the development of new concepts for mixing enhancement, stabilization of combustion systems, and drag reduction.

APPROACH: Research will seek to exploit our understanding of basic physical mechanisms in turbulent and reacting flows together with modern developments in control theory to explore feedback control concepts in a variety of generic flow configurations and environments. Key issues to be addressed include flow field state estimation, the receptivity of flows to controlled, actuator-generated disturbances, the effectiveness of sparse arrays of sensors and actuators, and the development of model-based flow control algorithms. The research will be interdisciplinary in nature, integrating developments in distributed parameter control theory and nonlinear dynamics with experimental and computational research on the dynamics of turbulent and reacting flows.

RESEARCH INITIATIVE

TITLE: Remote Sensing of Atomic Oxygen in the Thermosphere

FOCAL POINT: Dr William Blumberg, AFGL/LSI, (617) 377-3688

REFERENCE: Project 2310 Task G4

<u>FUNDING:</u>	<u>FY 89</u>	<u>FY 90</u>	<u>FY 91</u>	<u>TOTAL</u>
	\$200K	\$200K	\$200K	Continuing

OBJECTIVE: Build the fundamental understanding needed to conceive/refine spaceborne remote sensing capabilities to specify atmospheric density, temperature and wind structure in the thermosphere. The Air Force interests in this important, yet relatively unexplored, region of the atmosphere relate to drag effects on spacecraft, reentry vehicle discrimination, background limitations on IR surveillance systems, communications effects, and Over-The-Horizon (OTH) detection capabilities.

TECHNICAL DESCRIPTION: Atomic oxygen is the major source of electrons in the D, E, and F regions of the ionosphere; the dominant kinetic partner in the thermospheric energy balance above 100 km altitudes; the principal labile reactant in chemiluminescent airglow emissions (70-100 km); and a major component of total density above 120 km. Measurements of atomic oxygen can provide sufficient information to infer other important environmental parameters (e.g. total density, temperature and winds) needed to support and improve reliability and effectiveness of Air Force systems. Ground-based remote measurements of these parameters at these altitudes have severe technical limitations. In situ measurements are generally too expensive. Both methods are severely limited in their ability to provide the horizontal coverage needed. However, spaceborne interferometers designed to measure atomic oxygen may be feasible and could provide global measurements. This research will explore these interferometric possibilities.

APPROACH: Air Force Geophysics Laboratory in-house personnel and contract extramural scientists will perform this research which will concentrate on addressing several critically important theoretical and experimental problems associated with remote sensing of this rarified portion of the atmosphere. Theoretical issues to be explored include radiation transport inversion in limb geometry, pressure broadening of certain emissions, and vibrational excitation of major constituents. The broad experimental issues involve feasibility of various remote sensing approaches, interferometer requirements imposed by theory, and applicability of detector technology advances. After assessment of concepts that evolve from the first several years of research, a decision will be made on whether or not to enhance the budget significantly for FY 92 and beyond in order to develop a prototype system.

RESEARCH INITIATIVE

TITLE: Infrared Astronomy

FOCAL POINT: Dr Paul D. Levan, AFGL/OPC, (617) 377-4552

REFERENCE: Project 2311 Task G7

<u>FUNDING:</u>	<u>FY 89</u>	<u>FY 90</u>	<u>FY 91</u>	<u>TOTAL</u>
	\$400K	\$400K	\$400K	Continuing

OBJECTIVE: The objective is to determine the spectral contamination in the standard 8 to 14 micron bandpass posed by infrared celestial sources. Mechanisms will be identified that are responsible for broad feature emission in the wavelength region from 9 to 12 microns, in addition to those known for circumstellar silicates and silicon carbide molecules, that is manifest in a variety of infrared celestial source classes. The spectral and spatial content of the database collected at high spatial resolution with groundbased instrumentation will be utilized. As a complementary lower resolution/broader survey study, the Infrared Astronomical Satellite (IRAS) spectra of extended structures will be extracted in stressing regions of the Celestial Background that impact Surveillance System design, including solar system band emission structures and Galactic IR Cirrus complexes.

TECHNICAL DESCRIPTION: The AFGL array spectrometer to be used for the studies described above is a one of a kind instrument, utilizing a sophisticated 58 by 62 pixel Direct Read-out chip in contrast with the charge coupled device (CCD) technologies used extensively at visible wavelengths and prism slit spectrometer, both cooled to cryogenic temperatures. Astronomical sources selected on the basis of possible extension on the angular scale of several seconds of arc (10 microrad) are measured in conjunction with known unresolved sources for calibration of angular size, of atmospheric transmission variations with wavelength, and of instrumental effects. In particular, stars experiencing mass loss at high rates are expected to eject the material with a geometry compatible with local magnetic fields and the rotation of the star, resulting in disk-like and similar geometries. Complimentary with the above, the Infrared Astronomical Satellite IRAS database includes spectra in the 8 to 22 micron range that were not processed for celestial sources extended on the angular scale of minutes of arc (1 millirad). These structures include the solar system dust trails deposited by comets in their orbits, the band structures in the solar system zodiacal dust distribution, and the LWIR structures associated with the IR Cirrus phenomenon discovered by IRAS at 60 to 100 microns.

APPROACH: Groundbased Infrared Spectroscopy of Celestial Background Sources will be made utilizing the AFGL mosaic infrared array spectrometer on the 92-inch telescope of the University of Wyoming in a continuing program of high spatial and spectral resolution mapping. Research leading to improved

sensitivity of mosaic array instrumentation for Infrared Astronomy will be conducted in order to increase the observing efficiency of sources at fainter brightness levels. In a collaborative effort under contract with members of the Infrared Satellite Observatory team at the Gronigen Space Research Laboratory, spectral signatures of the spatially extended sources that were excluded from the original reduction of the IRAS Low Resolution Spectrometer database will be extracted.

RESEARCH INITIATIVE

TITLE: Enhancement of Life Sciences Research in Air Force Laboratories

FOCAL POINT: R. K. Dismukes AFOSR/NL, (202) 767-4278

REFERENCE: Projects 2312 and 2313

<u>FUNDING</u>	<u>FY 89</u>	<u>FY 90</u>	<u>FY 91</u>	<u>TOTAL</u>
	\$740K	\$740K	\$740K	Continuing

OBJECTIVE: The objective is to support innovative research tasks in life sciences at Air Force laboratories.

TECHNICAL DESCRIPTION: Several research topics have been worked up to date. The USAF School of Aerospace Medicine (USAFSAM) plans three new research tasks under this initiative. Research on subclinical cardiovascular disease will help determine the extent to which aircrew can continue to perform flight duties safely when they develop asymptomatic cardiovascular irregularities. Research on cerebral blood flow will help determine the causes of G-induced loss of consciousness and lead to ways to reduce the risk of mishaps in high-performance aircraft. Research on spatial disorientation will help prevent aircraft mishaps caused by aircrew disorientation. The Air Force Engineering Service Center (AFESC) will conduct research on developing microorganisms to degrade toxic chemicals spilled into the environment. Other research topics may also be developed within the Human Systems Division (HSD).

APPROACH: For each research topic proposed, the principle scientist develops a detailed research plan which is evaluated by AFOSR for technical content and management. An agreement is then negotiated for AFOSR to provide multiyear support (usually a task runs three years and may be renewed) and the laboratory to commit scientific personnel and facilities.

RESEARCH INITIATIVE

TITLE: Sensory Neurophysiology

FOCAL POINT: John F. Tangney, AFOSR/NL, (202) 767-5021

REFERENCE: Project 2313 Task A8

<u>FUNDING:</u>	<u>FY 89</u>	<u>FY 90</u>	<u>FY 91</u>	<u>TOTAL</u>
	\$740K	\$740K	\$740K	Continuing

OBJECTIVE: The objective is to bring neurophysiological studies to bear on psychophysical theories of the mechanisms of vision and hearing.

TECHNICAL DESCRIPTION: Vision and audition have traditionally been studied by two distinct communities of scientists: sensory neurophysiologists and sensory psychophysicists. By analogy, neurophysiologists might be thought of as studying the hardware of the brain and psychophysicists as studying the software. Obviously, there is much to be gained if the data and theories of these two communities can be brought together; however, that has been difficult because those data and theories take such different forms. This initiative will fund research at the intersection of these two communities.

APPROACH: We will seek psychophysical theories that can be constrained by neurophysiological data and will seek neurophysiological research capable of generating data of a sort with which psychophysical theory can be tested. We will especially encourage collaboration between physiologists and psychophysicists working on either vision or hearing.

V. SPECIAL PROGRAMS

AFOSR Focal Point: Col Theodore A. Johnson
Telephone: (202) 767-6010

In addition to the research conducted under the thirteen scientific projects, Defense Research Sciences (DRS) funding is used by AFOSR to execute the DRS program and to support several special research programs. This section briefly describes the special programs.

For FY 89 funding of the special programs will be shared between the Defense Research Sciences Program Element 0601102F and the University Research Initiative Program Element 0601103D.

Under the Summer Faculty Research Program (SFRP), Graduate Student Research Program (GSRP), Research Initiation Program (RIP), Laboratory Graduate Fellowship Program (LGFP), the University Resident Research Program (URRP), and the National Research Council Resident Research Associateship Program (NRC-RRA), university faculty and graduate students are given an opportunity to bring new ideas into the Air Force research community and to research Air Force problems in the university environment. Over 1600 faculty and graduate student researchers have participated in these programs.

Through these programs the Air Force supports research in all areas of science and technology. This sponsorship provides the strong scientific base of fundamental knowledge and new ideas essential to the Air Force. This narrative describes the planned FY 1989 special programs. The applications of these programs intersect the full spectrum of Air Force requirements. Programs such as AFIT and USAFA stimulate the development of in-house Air Force academic resources. Other programs have the side benefit of increasing the pool of scientists and engineers who are available to meet the challenge of future Air Force requirements.

PROGRAM DESCRIPTION:

1. EOARD Programs in Research: AFOSR will provide funds through EOARD to support European and Middle Eastern research opportunities of special interest to the Air Force and to enhance communication with those scientific communities. Small procurements will permit Air Force Systems Command to take advantage of unique capabilities of a European or Middle Eastern investigator or facility. The procurements are coordinated in advance with representatives of Air Force laboratories interested in the programs. Cooperative international visits of researchers will be funded under the Window on Science Program.

2. AFOSR Far East Office Support: AFOSR staffs and funds a liaison office located in Tokyo, Japan. The office's professional scientific staff establishes and maintains technical contacts with researchers at educational, industrial, and government research organizations in Japan and other free

world countries in the Far East to facilitate the interchange of scientific data.

3. FJSRL Support: Frank J. Seiler Research Laboratory performs research in aerospace mechanics, chemical sciences and physics. In addition to this FJSRL will provide support for USAF Academy faculty and cadet research conducted at FJSRL on topics of mutual interest to FJSRL and the researchers.

4. Summer Faculty Research Program (SFRP) and Research Initiation Program (RIP): The purpose of these programs is to develop the basis for continuing research of interest to the Air Force at the institution of the faculty member; to stimulate continuing relations among faculty members and professional peers in the Air Force; to enhance the research interests and capabilities of scientific and engineering educators; and to provide follow-on funding for research of particular promise that was started at an Air Force laboratory under the Summer Faculty Research Program.

Under these programs approximately 150 university faculty will be selected to conduct research at Air Force laboratories for ten weeks in FY 1989. Each participant will provide a report of their research to be consolidated into a single document. Under the RIP program approximately 75 minigrants will be awarded in FY 1989 to continue promising SFRP research efforts at the institution of the faculty member.

5. Graduate Student Research Program (GSRP): This program was started in 1982 as an adjunct to the SFRP. Its objectives are to permit graduate students to participate in research under direction of a faculty member at an Air Force Laboratory; stimulate professional association among graduate students, their supervising professors, and professional peers in the Air Force; further research objectives of the Air Force; and expose graduate students to potential thesis topics in areas of interest to the Air Force.

In 1982 seventeen graduate students were selected to participate in the program. Due to its success and popularity the program has continued to grow. In FY 1989 approximately 100 graduate students will be selected to perform research for ten weeks at Air Force laboratories.

6. University Resident Research Program (URRP). The URRP is designed to stimulate mutual research between Air Force Laboratories and institutions of higher education. Under the Intergovernmental Personnel Act faculty members are brought into Air Force laboratories to conduct research for one year after which they return to their university with a broadened awareness of Air Force research needs and operations. Extension to a second year of residency is possible.

For FY 1989 twenty-four URRP slots are allocated to the Laboratories. Since the program began in 1977, approximately 175 highly qualified university researchers have participated in the program. Advertisements in professional journals serve to increase university awareness of the URRP.

7. Historically Black Colleges and Universities (HBCU), and Minority Institutions Program. In 1979, AFOSR initiated a program to make over 100 Historically Black colleges aware of opportunities in Air Force research and

development. In 1985 AFOSR sponsored a Research Opportunities Workshop at the 10th National Conference on Blacks in Higher Education. From 1984 through 1987 visits were made to over sixty Historically Black Colleges to discuss opportunities in Air Force research and development with interested faculty researchers and administrators.

In 1988 we are issuing a separate broad agency announcement (BAA) calling for proposals and setting aside funds specifically for award to HBCU's and minority institutions.

8. Laboratory Graduate Fellowship Program (LGFP). The program is designed to stimulate doctoral candidate interest in Air Force laboratories and the research programs at those laboratories. In the 1987 academic year AFOSR initiated the Laboratory Graduate Fellowship Program. In the program, highly qualified graduates of U.S. colleges and universities (or international equivalent) currently pursuing doctoral degrees are granted fellowships under AFOSR sponsorship.

Each fellow is sponsored by an Air Force laboratory and performs the graduate studies at a college or university. The fellowship lasts for three years with a possible fourth year extension. Approximately 25 fellowships are awarded each year.

9. The AFSC/National Research Council (NRC) Resident Research Associateship Program. This program provides postdoctoral scientists and engineers opportunities to research problems of their own choice that are compatible with the research interests of selected sponsoring Air Force Laboratories. In this way, these researchers contribute to the overall research effort of the laboratories. This program is intended to be analogous to fellowships, associateships, and similar temporary programs at the doctoral level in universities and other organizations.

10. Defense Small Business Innovation Research Program (SBIR): AFOSR participates in the Defense Small Business Innovation Research Program. This program encourages small businesses that have strong research and development capabilities in science and engineering to submit proposals to the Departments of the Army, Navy, Air Force, the Defense Advanced Research Projects Agency, and the Defense Nuclear Agency. This program will support high quality research and development proposals on innovative concepts related to important defense related scientific or engineering problems. If the research is successful, these opportunities could significantly benefit the public.

11. Air Force Studies Board: AFOSR supports studies, surveys, and analysis of specified problems arising in accomplishing research and technical objectives of AFSC. The National Academy of Sciences will convene a working panel during the summer. The study topic will be selected at a later date.

12. Air Force Institute of Technology (AFIT) Research: AFOSR will provide funds to be used by AFIT Faculty primarily to procure equipment needed by AFIT to conduct approved research programs.

VI. ADDITIONAL AFOSR PUBLICATIONS

Research Interests

This book describes selected research interests of the Air Force Office of Scientific Research (AFOSR).

Recent Research Accomplishments of the Air Force Office of Scientific Research

This report is published to inform the scientific and technical community of some of the promising results of recent AFOSR research.

AFOSR Technical Report Summaries

This report is published quarterly and consists of a brief summary of each AFOSR technical report received by AFOSR/X01 and submitted to the Defense Technical Information Center (DTIC).

These publications are available from:

AFOSR/X01
Bolling AFB, DC 20332-6448